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MOISTURE CONTENT AND SHRINKAGE OF FORAGE AND THE RELATION OF THESE FACTORS TO THE ACCURACY OF EXPERIMENTAL DATA.

By H. N. VINALL, *Agronomist*, and ROLAND MCKEE, *Assistant Agrostologist, Office of Forage-Crop Investigations.*[1]

CONTENTS.

	Page.		Page
Introduction	1	Variation in the moisture content of growing alfalfa during a single day	31
General plan of the experiments	2	Moisture content of baled hay	31
Use of samples in correcting forage yields	3	Shrinkage of hay after storing and variation in weight due to changes in atmospheric humidity	32
Relation of the stage of growth of forage plants to their moisture content	22	Summary	36
Loss of moisture in forage during the early stages of curing	27		

INTRODUCTION.

Agronomic literature contains but little in the way of well-planned investigations on the subject of the moisture content of different forage plants either green or cured, a matter which is intimately related in farm practice to the proper handling and wise marketing of forage crops and in investigational work to the correct interpretation of yield data. This subject is of sufficient importance to justify much more attention than has previously been given to it by experimenters. Careful investigators have long recognized that many of the published data on forage crops are inaccurate, on account of the uncertain amount of water included in the yields.

The term "air dry," as used in the investigations described in the following pages, refers to that stage of curing when the humidity of the forage and the humidity of the atmosphere have reached a state of equilibrium. The percentage of moisture in the forage when air dry of course varies with the changes in atmospheric humidity,

[1] Messrs. W. J. Morse, H. L. Westover, M. W. Evans, A. B. Cron, and R. E. Getty, members of the staff of the Office of Forage-Crop Investigations, have contributed quite largely to this publication by their assistance in collecting and preparing records of the numerous samples required.

but this variation is within rather narrow limits. The term "field cured" is more indefinite, denoting that condition of forage which obtains in general farm practice when the hay or fodder is considered sufficiently well cured or dried so that it will not spoil when placed in bales, stacks, or in a haymow. In this stage the forage is very seldom completely air dry.

Most publications on forage crops use the term "field cured" to denote the condition of the forage under consideration, but such a term does not imply a uniform percentage of moisture, and little or no care has ever been used to indicate even approximately the moisture content of the forage when the yields were determined. It is, therefore, impossible to interpret correctly many data found in such publications.

The variation in the moisture content of forage when yields are taken is often greater than the actual difference in yield that we may expect from improved varieties or improved methods. There is little dependence therefore to be placed in experimental results along these lines until this factor of error is eliminated, or at least greatly reduced. The data presented in this bulletin are sufficient to suggest a remedy for this difficulty, and it is hoped that experimenters will consider carefully the method here indicated.

Aside from the experimental value of this work, it has an economic significance, in that it points out the relative weight value of forages at different stages of maturity. However, the economic side of the question is not discussed in detail and is given only as it forms a part of the experimental data presented.

GENERAL PLAN OF THE EXPERIMENTS.

During 1914 a series of experiments was carried out to secure data on which to base a sampling system that would give greater accuracy to field tests in forage experiments. In connection with the efficiency of the sample method, investigations were also carried on to determine the amount of moisture in forage plants at different stages of development, the variation in moisture content due to locality and to cutting at different times of the day, and the differences in loss of weight when samples are dried in the sun as compared with those dried in the shade. Information was also secured on the rate of moisture loss in forage in the early stages of curing and the changes in moisture content of hay stored in bales and loose in a barn.

In conducting the experiments at the various places the methods followed were the same or varied only in minor details. Half-bushel and bushel cotton bags were used to receive all samples except the largest, for which common burlap grain bags having a capacity of 2 bushels were used. For inclosing the bales of hay a close-weave burlap was used. In taking samples of field-cured forage, care was

used to have each sample representative of the entire crop. Material from the outside as well as from the middle and bottom of the windrows or shocks was included.

Samples of green material were taken by cutting the plants either by hand or with machinery, each sample including only that part of the plant that is used in making hay or fodder. The samples of different sizes in both the field-cured and green material were replicated five or six times, and each sample was marked with a tag bearing a number and other data necessary for identification. In taking samples, the work was done as quickly as possible, to avoid loss in weight by evaporation. Each sample as soon as prepared was weighed immediately.

After the samples [1] were placed in the containers and weighed, they were stored in a favorable place to facilitate further drying and at the same time were given protection from rain.

In ascertaining the total water and dry-matter content of the various samples, determinations were made by the usual method of oven drying. For this purpose a special oven having a capacity of 164 cubic feet was built. Steam heat under pressure was used and a temperature of 100° C., or a little above, was maintained.

In the following account, the outline for each experiment is given as it was carried out at the various stations, and this outline is followed by a tabulated statement of the original data from which the summaries are prepared and conclusions drawn.

USE OF SAMPLES IN CORRECTING FORAGE YIELDS.

McKee, in the Journal of the American Society of Agronomy,[2] gives a general discussion of moisture as a factor of error in determining forage yields, wherein it is suggested that forage-yield data can be made much more nearly comparable if small samples taken at the time of weighing field-cured or green material are used in determining the moisture content of the material and these data used in reducing the yield either to an air-dry or to a dry-matter basis.

In the experiments described in the present bulletin, the efficiency of correcting ordinary green and field-cured forage weights with 2, 4, 6, 8, 12, or 16 pound samples was determined with the following crops: At Arlington Farm, Va., alfalfa and a mixture of tall oat-grass and orchard grass; at Chico, Cal., alfalfa; at New London, Ohio, timothy; at Amarillo, Tex., sorghum; and at Hays, Kans., sorghum. To provide a basis for checking up the moisture loss in small samples, 100 pounds of ordinary field-cured forage were taken from the shock

[1] The samples of tall oat-grass and orchard grass at Arlington Farm, Va., were prepared by H. N. Vinall and H. L. Westover; the alfalfa at Arlington Farm, Va., by W. J. Morse; the alfalfa at Chico, Cal., by Roland McKee; the timothy at New London, Ohio, by M. W. Evans; the sorghums at Amarillo, Tex., by A. B. Cron, and at Hays, Kans., by R. E. Getty.

[2] McKee, Roland. Moisture as a factor of error in determining forage yields. *In* Jour. Amer. Soc. Agron., v. 6, no. 3, p. 113–117, 1914.

or windrow and 500 pounds of green forage were taken immediately after cutting and placed on a canvas to prevent loss of weight other than moisture. When the forage on the canvas had become sufficiently dry, these bulk lots were placed in burlap bags and kept in an open shelter until they ceased to lose weight.

Composite samples, 2, 4, 6, and 8 pounds in size, of field-cured forage, part from the outside and part from the inside of shocks, were secured at the same time and from the same material as the 100-pound lot before mentioned. These samples were weighed at once and put aside to become perfectly air dry. Samples, 4, 8, 12, and 16 pounds in size, of green forage were taken immediately after cutting and were treated similarly. Samples were replicated five or six times to check the variation due to sampling. All samples were taken at the stage of maturity generally recognized as the proper cutting time for each crop. The samples were kept in a shelter and weighed at intervals until they ceased to lose weight. They were then shipped to Washington, D. C., for the purpose of reducing them to a moisture-free state in the drying oven. The intention was to secure samples of timothy at both New London, Ohio, and Arlington Farm, Va., so that each crop would be handled at two stations, but an unfavorable season caused a failure of the timothy crop at Arlington Farm, and it was found necessary to substitute there the mixture of tall oat-grass and orchard grass.

In Table I an attempt has been made to arrange the data so as to make the conclusions to be derived from them as clear as possible. Column 1 contains the number under which the identity of the sample was preserved from the time it was prepared until it was finally weighed from the drying oven.

Column 2 gives the original weight of the sample, whether green or field cured.

Column 3 gives the weight of the sample at a date between the time it was prepared and the date when it was considered air dry. This column is intended to show about what time is required for each sample to lose most of its moisture, that is, when it was drier than field cured, but in most cases not yet air dry. This column is blank in sections A and B because no weights were obtained between the date of cutting and the date when the samples were completely air dry.

Column 4 carries the air-dry weight of the sample. In some cases this was the weight obtained just before the sample was placed in the drying oven, but where an earlier weighing made at the field station showed the sample to be practically as dry at that time, the earlier weight is given.

Column 5 gives the weight of the samples oven dry and represents the dry matter contained in each sample as nearly as it can be determined in an ordinary oven.

Column 6 carries a statement of the percentage of moisture in each of the original samples, as determined by the difference between the original and the oven-dry weights. It is recognized that this loss may not necessarily be exclusively water. Slight losses may have taken place through volatilization of substances other than water or through fermentation due to enzyms or bacteria, but such losses are undoubtedly small when the hay has been quickly cured. The percentages as given are determined by using the original weights of the samples as the base. It is recognized that this practice is open to criticism, owing to the fact that the original weights vary in relative importance, due to the differing percentages of moisture which the samples contain. This criticism is of little importance in the present case, however, since the percentage of moisture is very nearly the same in each group where a comparison is made. The use of the absolute dry matter as a base from which to figure the percentages was tried, but this method seemed impracticable, because it makes the percentages so at variance with the moisture percentages as usually given. Column 6 also gives the means of groups of three and groups of five or six samples, with their probable errors. In tables where there are only five samples in each class the second group of three represented by the second mean includes the remaining two samples and the one next above, which has already been considered in the first group. For example, in section A the first "mean of 3" is based on samples 1, 2, and 3, and the second "mean of 3" on samples 3, 4, and 5. These means are set in black-faced type, so that they will be apparent at a glance. The consistency in the percentages of moisture in each set of samples is remarkable. In only one case has the probable error for the group of six samples exceeded 1 per cent, and the probable error for a single sample averaged considerably less than 1 per cent, although in exceptional cases it approached 2.5 per cent. The probable error was chosen as the most efficient measure of the comparative reliability of the different sizes of samples and methods of sampling. Since the moisture is here stated in percentages, means of practically the same size are dealt with, and the need for a term like the coefficient of variability is lacking.

Column 7, as shown by the heading, is a record of the percentage of moisture in the air-dry material, the weight of which is shown in column 4.

Column 8 gives the percentage of moisture which was lost in reducing the material from its original state to an air-dry condition. The base on which this percentage was calculated is the weight of the original material given in column 2. The actual losses of weight in 100 pounds of field-cured and 500 pounds of green material under the same conditions as those surrounding the samples are given following the tabulation of sample weights.

TABLE I.—*Comparison of different-sized samples of forage.*

SECTION A.—GREEN ALFALFA COLLECTED AT ARLINGTON FARM.

[Dates of weighing: Original material, Oct. 16; air-dry material, Feb. 2.]

Sample.	Weight.				Moisture.		
	Original.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	Ounces.	*Ounces.*	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*
No. 1	64		18.0	16.0	75.0	11.1	71.9
No. 2	64		18.0	16.5	74.2	8.3	71.9
No. 3	64		18.5	16.0	75.0	13.5	71.1
Mean of 3					**74.7**±0.148		
No. 4	64		20.0	18.0	71.9	10.0	68.8
No. 5	64		18.5	16.5	74.2	10.8	71.1
Mean of 3					**73.7**± .510		
Mean of 5					**74.1**± .344	**10.7**±0.510	**71.0**±0.237
Error of 1					± .769		
No. 6	128		38.0	34.0	75.4	10.5	70.3
No. 7	128		35.0	31.5	75.4	10.0	72.7
No. 8	128		35.0	31.5	75.4	10.0	72.7
Mean of 3					**74.7**± .367		
No. 9	128		36.5	32.5	74.6	10.9	71.5
No. 10	128		36.0	32.0	75.0	11.1	71.9
Mean of 3					**75.0**± .127		
Mean of 5					**74.8**± .225	**10.5**± .129	**71.8**± .259
Error of 1					± .501		
No. 11	192		51.5	46.0	76.0	10.7	73.2
No. 12	192		52.5	46.5	75.8	11.2	72.7
No. 13	192		54.0	48.0	75.0	11.1	71.9
Mean of 3					**75.6**± .168		
No. 14	192		53.5	47.5	75.3	11.2	72.2
No. 15	192		52.5	47.0	75.5	10.5	72.7
Mean of 3					**75.2**± .081		
Mean of 5					**75.5**± .160	**10.9**± .107	**72.5**± .136
Error of 1					± .248		
No. 16	256		65.0	58.0	77.3	10.8	74.6
No. 17	256		67.5	59.5	76.8	11.9	73.6
No. 18	256		68.5	61.5	76.0	10.2	73.2
Mean of 3					**76.7**± .207		
No. 19	256		67.5	61.0	76.2	9.6	73.6
No. 20	256		68.5	60.5	76.4	11.7	73.2
Mean of 3					**76.2**± .063		
Mean of 5					**76.5**± .155	**10.8**± .251	**73.6**± .155
Error of 1					± .347		

SECTION B.—FIELD-CURED[1] ALFALFA COLLECTED AT ARLINGTON FARM.

[Dates of weighing: Original material, Oct. 20; air-dry material, Feb. 2.]

No. 21	32		32.5	29.0	9.3	9.6	
No. 22	32		33.0	29.5	7.7	9.6	
No. 23	32		32.5	29.0	9.3	9.6	
Mean of 3					**8.8**±0.294		
No. 24	32		32.0	29.0	9.3	9.3	
No. 25	32		32.0	29.0	9.3	9.3	
Mean of 3					**9.3**±0		
Mean of 5					**9.0**± .193	**9.5**±0.045	
Error of 1					± .432		

[1] Owing to unfavorable weather conditions, this material was moved into a greenhouse shortly after it was cut, and the curing was finished there. This explains the unusual dryness of these samples. They are not to be considered field cured, and the percentage of moisture lost in air drying is therefore disregarded.

TABLE I.—*Comparison of different-sized samples of forage*—Continued.

SECTION B.—FIELD-CURED ALFALFA COLLECTED AT ARLINGTON FARM—Continued.

Sample.	Weight.				Moisture.		
	Original.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	Ounces.	*Ounces.*	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*
No. 26	64		64.0	57.5	10.1	10.1	
No. 27	64		64.5	57.5	10.1	10.7	
No. 28	64		63.5	57.0	10.8	10.2	
Mean of 3					**10.3**± .130		
No. 29	64		63.5	57.0	10.8	10.2	
No. 30	64		63.0	57.5	10.2	8.7	
Mean of 3					**10.6**± .110		
Mean of 5					**10.4**± .099	**10.0**± .203	
Error of 1					± .221		
No. 31	96		92.5	84.0	12.4	9.1	
No. 32	96		94.5	85.0	11.4	10.0	
No. 33	96		92.5	83.5	13.0	9.7	
Mean of 3					**12.3**± .258		
No. 34	96		93.0	85.0	11.4	8.6	
No. 35	96		92.0	83.0	13.5	9.8	
Mean of 3					**12.6**± .349		
Mean of 5					**12.3**± .257	**9.4**± .156	
Error of 1					± .576		
No. 36	128		126.5	113.0	11.5	10.6	
No. 37	128		128.0	113.0	11.5	11.5	
No. 38	128		127.0	112.5	12.1	11.3	
Mean of 3					**11.7**± .110		
No. 39	128		126.0	112.0	12.3	11.1	
No. 40	128		124.5	111.5	12.8	10.3	
Mean of 3					**12.4**± .115		
Mean of 5					**12.0**± .181	**11.0**± .135	
Error of 1					± .406		

SECTION C.—GREEN ALFALFA COLLECTED AT CHICO, CAL.

[Dates of weighing: Original material, June 11; intermediate, June 30; air-dry material, July 23.]

No. 501	60.5	17.50	17.25	16.0	73.6	7.2	71.5
No. 502	60.5	17.00	16.75	15.5	74.4	7.5	72.3
No. 503	60.5	16.00	15.75	14.5	76.0	7.8	74.0
Mean of 3					**74.7**±0.389		
No. 504	60.5	16.25	16.25	15.0	75.2	7.5	73.2
No. 505	60.5	16.50	16.00	14.5	76.0	9.3	73.5
No. 506	60.5	16.00	16.00	15.0	75.2	6.2	73.2
Mean of 3					**75.5**± .148		
Mean of 6					**75.1**± .258	**7.6**±0.253	**73.0**±0.249
Error of 1					± .576		
No. 507	123.2	33.95	32.70	29.0	76.5	11.2	72.5
No. 508	123.2	31.95	30.45	27.0	78.1	11.4	75.3
No. 509	124.5	36.25	32.75	30.0	75.8	8.4	73.7
Mean of 3					**76.8**± .375		
No. 510	123.2	34.20	32.45	29.0	76.4	10.7	73.7
No. 511	124.5	35.00	33.25	30.0	75.8	9.6	73.3
No. 512	124.5	33.75	30.25	28.0	77.5	7.4	75.7
Mean of 3					**76.6**± .275		
Mean of 6					**76.7**± .234	**9.8**± .407	**74.2**± .258
Error of 1					± .574		

TABLE I.—*Comparison of different-sized samples of forage*—Continued.

SECTION C.—GREEN ALFALFA COLLECTED AT CHICO, CAL.—Continued.

Sample.	Weight.				Moisture.		
	Original.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	Ounces.	*Ounces.*	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*
No. 513	187.2	50.20	45.20	40.5	78.4	10.2	75.9
No. 514	187.2	50.20	45.70	41.0	78.1	10.2	75.6
No. 515	187.2	51.70	46.20	41.5	77.8	10.0	75.3
Mean of 3					**78.1**± .095		
No. 516	187.2	52.95	48.20	43.0	77.0	10.7	74.3
No. 517	187.2	50.95	46.70	41.5	77.8	11.0	75.1
No. 518	187.2	50.20	47.20	42.5	77.3	9.8	74.8
Mean of 3					**77.4**± .125		
Mean of 6					**77.7**± .129	**10.3**± .113	**75.2**± .144
Error of 1					± .316		
No. 519	251.2	72.70	61.45	55.5	77.9	9.6	75.5
No. 520	251.2	73.45	62.95	56.5	77.5	10.1	74.9
No. 521	251.2	72.20	59.95	53.5	78.7	10.5	76.1
Mean of 3					**78.0**± .195		
No. 522	251.2	69.95	60.70	54.5	78.3	10.1	75.7
No. 523	251.2	76.95	62.20	56.0	77.7	10.0	75.2
No. 524	251.2	71.70	62.20	55.5	77.9	10.7	75.2
Mean of 3					**78.0**± .098		
Mean of 6					**78.0**± .109	**10.2**± .098	**75.4**± .108
Error of 1					± .267		

SECTION D.—FIELD-CURED ALFALFA COLLECTED AT CHICO, CAL.

[Dates of weighing: Original material, June 13; intermediate, June 30; air-dry material, July 23.]

No. 525	28.5	24.00	24.00	22.5	21.0	6.2	15.8
No. 526	28.5	25.25	25.25	23.5	17.5	7.0	11.4
No. 527	28.5	24.75	25.00	23.0	19.0	8.0	12.3
Mean of 3					**19.2**±0.511		
No. 528	28.5	23.50	23.75	22.0	22.5	7.3	16.6
No. 529	28.5	24.00	25.50	22.5	21.0	11.7	10.5
No. 530	27.2	23.70	23.70	21.0	22.7	11.3	12.8
Mean of 3					**22.0**± .297		
Mean of 6					**20.6**± .558	**8.6**±0.587	**13.2**±0.611
Error of 1					±1.247		
No. 531	59.2	51.20	51.45	46.5	21.2	9.5	13.0
No. 532	59.2	49.95	50.45	45.5	23.0	9.6	14.8
No. 533	59.2	48.45	49.20	44.0	25.5	10.4	16.8
Mean of 3					**23.2**± .685		
No. 534	59.2	48.70	48.20	43.5	26.3	9.7	18.6
No. 535	59.2	50.45	50.70	46.0	22.0	9.3	14.3
No. 536	59.2	48.45	48.70	44.0	25.5	9.8	17.7
Mean of 3					**24.6**± .727		
Mean of 6					**23.9**± .585	**9.7**± .095	**15.9**± .548
Error of 1					±1.308		
No. 537	91.2	75.70	75.45	68.5	24.8	9.1	17.2
No. 538	91.2	78.70	77.95	71.0	22.0	9.0	14.5
No. 539	91.2	78.20	77.95	71.0	22.0	9.0	14.5
Mean of 3					**22.9**± .514		
No. 540	91.2	77.45	76.70	69.5	23.5	9.5	15.9
No. 541	91.2	79.95	80.20	72.5	20.3	9.6	12.1
No. 542	91.2	79.20	78.95	71.5	21.5	9.4	13.4
Mean of 3					**21.8**± .514		
Mean of 6					**22.4**± .399	**9.3**± .067	**14.6**± .452
Error of 1					± .977		

TABLE I.—*Comparison of different-sized samples of forage*—Continued.

SECTION D.—FIELD-CURED ALFALFA COLLECTED AT CHICO, CAL.—Continued.

Sample.	Weight.				Moisture.		
	Original.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	Ounces.	*Ounces.*	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*
No. 543	114.0	96.25	99.00	87.5	23.3	11.6	13.1
No. 544	116.5	105.00	105.75	94.25	17.7	10.9	9.2
No. 545	115.25	101.50	102.75	91.75	20.5	10.7	10.8
Mean of 3					**20.5± .971**		
No. 546	115.75	100.50	101.25	90.00	22.3	11.2	12.6
No. 547	115.75	96.75	97.75	85.75	21.0	12.3	15.6
No. 548	116.25	92.75	94.00	82.25	29.3	12.5	19.1
Mean of 3					**24.2±1.421**		
Mean of 6					**22.4±1.454**	**11.5± .186**	**13.4± .089**
Error of 1					**±2.402**		

SECTION E.—GREEN TALL OAT-GRASS AND ORCHARD GRASS[1] COLLECTED AT ARLINGTON FARM.

[Dates of weighing: Original material, June 2; intermediate, July 3; air-dry material, July 18.]

No. 41	64	22.0	22.5	19.0	70.3	15.5	65.5
No. 42	64	21.5	21.5	18.0	71.8	16.2	66.4
No. 43	64	22.0	22.5	19.0	70.3	15.5	65.5
Mean of 3					**70.8±0.275**		
No. 44	64	22.0	21.5	18.0	71.8	16.2	66.4
No. 45	64	21.5	22.0	18.5	71.1	15.8	65.6
Mean of 3					**71.1± .239**		
Mean of 5					**71.1± .203**	**15.8±0.095**	**65.9±0.129**
Error of 1					**± .435**		
No. 46	128	45.5	46.0	38.0	70.3	17.4	64.1
No. 47	128	43.0	42.0	35.0	72.6	16.6	67.2
No. 48	128	43.0	43.0	35.5	72.2	17.3	66.4
Mean of 3					**71.7± .391**		
No. 49	128	46.5	45.5	37.5	70.7	17.5	64.4
No. 50	128	43.0	44.0	38.0	71.9	18.1	65.6
Mean of 3					**71.6± .252**		
Mean of 5					**71.5± .268**	**17.4± .145**	**65.5± .353**
Error of 1					**± .599**		
No. 51	128	46.0	48.0	38.5	69.9	19.7	62.5
No. 52	128	46.5	48.0	36.5	71.5	23.9	62.5
No. 53	128	43.0	42.0	34.5	73.0	17.8	67.2
Mean of 3					**71.5± .493**		
No. 54	128	47.5	47.5	38.5	69.9	18.9	62.8
No. 55	128	46.8	48.0	39.0	69.6	18.7	62.5
Mean of 3					**70.8± .599**		
Mean of 5					**70.8± .391**	**19.8± .204**	**63.5± .558**
Error of 1					**± .873**		
No. 56	192	63.0	65.0	53.0	72.4	18.4	66.2
No. 57	192	65.0	64.5	53.5	72.2	17.0	66.4
No. 58	192	63.0	65.5	54.0	71.9	17.5	65.9
Mean of 3					**72.2± .081**		
No. 59	192	63.5	64.5	53.0	72.4	17.7	66.4
No. 60	192	63.5	64.5	53.5	72.2	17.0	66.4
Mean of 3					**72.2± .081**		
Mean of 5					**72.2± .056**	**17.5± .157**	**66.3± .060**
Error of 1					**± .124**		

[1] Samples 46, 47, 48, 49, and 50 were cured in the shade for comparison with the other group of 8-pound samples which were cured in the sun.

TABLE I.—*Comparison of different-sized samples of forage*—Continued.

SECTION E.—GREEN TALL OAT-GRASS AND ORCHARD GRASS COLLECTED AT ARLINGTON FARM—Con.

Sample.	Weight.				Moisture.		
	Original.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	Ounces.	*Ounces.*	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*
No. 61	256	83.0	82.8	68.5	73.2	17.1	67.6
No. 62	256	83.3	82.8	68.0	73.4	17.8	67.6
No. 63	256	88.0	89.5	73.5	71.3	17.7	65.1
Mean of 3					**72.6**± .369		
No. 64	256	84.5	82.5	68.0	73.4	17.6	67.8
No. 65	256	77.5	78.0	64.0	75.0	17.8	69.5
Mean of 3					**73.2**± .590		
Mean of 5					**73.3**± .355	**17.6**± .079	**67.5**± .424
Error of 1					± .793		
SECTION F.—FIELD-CURED TALL OAT-GRASS AND ORCHARD GRASS COLLECTED AT ARLINGTON FARM.							
[Dates of weighing: Original material, June 6; intermediate, July 3; air-dry material, July 18.]							
No. 66	32	26.0	26.5	22.0	31.2	16.8	17.1
No. 67	32	27.0	27.0	22.5	29.7	16.6	15.5
No. 68	32	26.5	26.0	21.5	32.8	17.3	18.6
Mean of 3					**31.2**±0.488		
No. 69	32	26.5	27.0	22.0	31.2	18.5	15.5
No. 70	32	26.0	26.0	21.0	34.3	19.1	18.6
Mean of 3					**32.8**± .493		
Mean of 5					**31.8**± .409	**17.7**±0.295	**17.1**±0.418
Error of 1					± .914		
No. 71	64	53.5	52.5	43.5	32.0	24.3	17.9
No. 72	64	57.0	57.0	47.5	25.8	21.6	10.8
No. 73	64	53.5	53.0	42.5	33.6	19.8	17.1
Mean of 3					**30.5**±1.310		
No. 74	64	56.0	55.5	46.5	27.3	16.2	13.2
No. 75	64	56.0	56.0	46.5	27.3	17.7	11.7
Mean of 3					**29.4**±1.157		
Mean of 5					**29.2**± .750	**19.9**± .861	**14.1**± .863
Error of 1					±1.677		
No. 76	96	84.0	82.5	68.0	29.2	17.6	14.0
No. 77	96	83.5	84.5	70.5	26.6	16.6	12.0
No. 78	96	83.0	82.0	67.5	29.6	17.6	14.5
Mean of 3					**28.5**± .518		
No. 79	96	83.3	83.0	68.5	28.5	17.4	13.5
No. 80	96	86.3	87.0	72.0	25.0	17.2	9.3
Mean of 3					**27.7**± .764		
Mean of 5					**27.8**± .522	**17.3**± .112	**12.7**± .566
Error of 1					±1.167		
No. 81	128	113.0	116.5	93.5	26.9	19.7	9.0
No. 82	128	116.5	116.5	94.0	26.6	19.4	9.0
No. 83	128	115.0	116.0	93.0	27.4	19.8	9.3
Mean of 3					**27.0**± .129		
No. 84	128	114.0	114.5	93.0	27.4	18.8	10.5
No. 85	128	115.5	115.5	93.5	26.9	19.1	9.7
Mean of 3					**27.2**± .093		
Mean of 5					**27.2**± .136	**19.4**± .113	**9.5**± .169
Error of 1					± .304		

TABLE I.—*Comparison of different-sized samples of forage*—Continued.

SECTION G.—GREEN TIMOTHY COLLECTED AT NEW LONDON, OHIO.

[Dates of weighing: Original material, July 10; intermediate, Sept. 2; air-dry material, Sept. 28.]

Sample.	Weight.				Moisture.		
	Original.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	Ounces.	*Ounces.*	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*
No. 401	64	33	31	26.5	58.6	14.5	51.3
No. 402	67	33	32	27.5	59.0	14.0	52.3
No. 403	63	32	31	26.0	58.8	16.1	50.8
Mean of 3					**58.8±0.068**		
No. 404	65	33	33	28.0	57.0	15.1	49.3
No. 405	64	33	32	27.0	57.9	15.6	50.0
No. 406	68	35	34	29.0	57.4	14.7	50.0
Mean of 3					**57.4± .144**		
Mean of 6					**58.1± .204**	**15.0±0.192**	**50.6±0.272**
Error of 1					**± .499**		
No. 407	134	67	66	56.0	58.2	15.1	50.8
No. 408	131	65	63	53.5	59.2	15.0	52.0
No. 409	131	65	64	54.0	58.8	15.6	51.1
Mean of 3					**58.7± .161**		
No. 410	128	67	66	56.0	56.3	15.1	48.5
No. 411	128	68	66	56.0	56.3	15.1	48.5
No. 412	128	66	64	54.0	57.8	15.6	50.0
Mean of 3					**56.8± .275**		
Mean of 6					**57.8± .310**	**15.3± .070**	**50.2± .359**
Error of 1					**± .760**		
No. 413	195	100	98	83.5	57.2	14.7	49.8
No. 414	192	97	95	81.5	57.6	14.1	50.6
No. 415	192	99	97	81.5	57.6	15.9	49.5
Mean of 3					**57.5± .074**		
No. 416	192	95	93	79.5	58.6	14.5	51.6
No. 417	192	96	95	80.0	58.4	15.7	51.6
No. 418	192	96	96	81.5	57.6	15.1	50.0
Mean of 3					**58.2± .168**		
Mean of 6					**57.8± .137**	**15.0± .176**	**50.5± .230**
Error of 1					**± .335**		
No. 419	256	128	126	107.0	58.2	15.1	50.8
No. 420	256	126	123	105.0	59.0	14.6	52.0
No. 421	256	130	127	108.5	57.7	14.6	50.4
Mean of 3					**58.3± .208**		
No. 422	256	126	125	105.0	59.0	16.0	51.2
No. 423	256	126	126	105.5	58.8	16.3	50.8
No. 424	256	130	129	109.0	57.5	15.5	49.7
Mean of 3					**58.4± .260**		
Mean of 6					**58.4± .167**	**15.4± .179**	**50.8± .194**
Error of 1					**± .410**		

SECTION H.—FIELD-CURED TIMOTHY COLLECTED AT NEW LONDON, OHIO.

[Dates of weighing: Original material, July 11; intermediate, Aug. 27; air-dry material, Sept. 28.]

No. 425	32	30	30	26.0	18.8	13.3	6.3
No. 426	32	30	30	26.0	18.8	13.3	6.3
No. 427	32	30	31	26.5	17.2	14.5	3.2
Mean of 3					**18.3±0.294**		
No. 428	32	30	30	25.5	20.4	15.0	6.3
No. 429	32	30	31	26.0	18.8	13.3	3.2
No. 430	32	29	30	26.0	18.8	13.3	6.3
Mean of 3					**19.3± .294**		
Mean of 6					**18.8± .254**	**13.8±0.192**	**5.3±0.402**
Error of 1					**± .623**		

TABLE I.—*Comparison of different-sized samples of forage*—Continued.

SECTION H.—FIELD-CURED TIMOTHY COLLECTED AT NEW LONDON, OHIO—Continued.

Sample.	Weight.				Moisture.		
	Original.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	Ounces.	*Ounces.*	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*
No. 431	64	59	60	51.5	19.6	14.0	6.3
No. 432	64	59	59	51.5	19.6	12.7	7.9
No. 433	64	58	58	50.0	21.9	13.7	9.4
Mean of 3					**20.4**± .422		
No. 434	64	57	58	49.5	22.7	14.6	9.4
No. 435	64	58	60	51.0	20.3	15.0	6.3
No. 436	64	59	60	51.0	20.3	15.0	6.3
Mean of 3					**21.1**± .440		
Mean of 6					**20.7**± .321	**14.2**± .224	**7.6** ± .384
Error of 1					± .786		
No. 437	96	87	88	75.5	21.4	14.1	8.4
No. 438	96	88	89	75.5	21.4	15.1	7.3
No. 439	96	89	88	75.5	21.4	14.1	8.4
Mean of 3					**21.4**± .000		
No. 440	96	88	88	76.0	20.8	13.6	8.4
No. 441	96	88	89	75.5	21.4	15.0	7.3
No. 442	96	85	85	73.0	24.0	14.1	11.5
Mean of 3					**22.1**± .541		
Mean of 6					**21.7**± .285	**14.3**± .148.	**8.6**± .388
Error of 1					± .697		
No. 443	128	118	118	101.0	21.2	14.4	7.9
No. 444	128	118	117	101.0	21.2	13.7	8.6
No. 445	128	118	119	102.5	19.9	13.8	7.1
Mean of 3					**20.8**± .239		
No. 446	128	119	118	101.5	20.6	14.0	7.9
No. 447	128	121	122	104.0	18.8	14.7	4.7
No. 448	128	120	120	104.0	18.8	13.3	6.3
Mean of 3					**19.4**± .331		
Mean of 6					**20.1**± .277	**14.0**± .127	**7.1**± .354
Error of 1					± .678		

SECTION I.—GREEN RED AMBER SORGHUM COLLECTED AT AMARILLO, TEX.

[Dates of weighing: Original material, Sept. 4; intermediate, Dec. 5; air-dry material, Dec. 16.]

No. 201	64.0	32.0	25.0	16.5	74.2	34.0	60.9
No. 202	65.0	32.0	25.0	15.5	76.2	38.0	61.5
No. 203	70.0	35.0	28.0	19.0	72.9	32.1	60.0
Mean of 3					**74.4**±0.528		
No. 204	64.0	34.0	27.0	16.5	74.2	38.9	57.8
No. 205	72.0	40.0	33.0	22.5	68.7	31.8	54.2
Mean of 3					**71.9**± .897		
Mean of 5					**73.2**± .516	**34.8**±0.894	**58.9**±0.801
Error of 1					±1.153		
No. 206	137.0	73.0	65.0	39.0	71.5	40.0	52.6
No. 207	128.0	64.0	55.5	35.5	72.3	36.0	56.6
No. 208	136.0	76.0	66.0	40.0	70.6	39.3	51.5
Mean of 3					**71.5**± .270		
No. 209	139.0	72.0	64.0	41.0	70.5	35.9	54.0
No. 210[1]							
Mean of 4					**71.2**± .248	**37.9**± .630	**53.7**± .643
Error of 1					± .494		
No. 211	204.0	110.0	100.5	61.0	70.1	39.3	50.7
No. 212	192.0	96.0	87.0	52.5	72.7	39.7	54.7
No. 213	200.0	110.0	100.0	61.0	69.5	39.5	50.0
Mean of 3					**70.8**± .541		

[1] Sample injured by mice.

TABLE I.—*Comparison of different-sized samples of forage*—Continued.

SECTION I.—GREEN RED AMBER SORGHUM COLLECTED AT AMARILLO, TEX.—Continued.

Sample.	Weight.				Moisture.		
	Original.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	Ounces.	*Ounces.*	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*
No. 214	196.0	106.0	97.5	62.5	68.1	35.9	50.3
No. 215	202.0	104.0	96.5	61.0	69.8	36.8	52.2
Mean of 3					**69.1**± .148		
Mean of 5					**70.1**± .451	**38.1**± .476	**51.6**± .523
Error of 1					±1.010		
No. 216	260.0	131.0	122.5	76.5	70.6	37.6	52.9
No. 217	258.0	131.0	122.0	78.0	69.8	36.1	52.7
No. 218	260.0	133.0	125.5	78.0	70.0	37.8	51.7
Mean of 3					**70.1**± .133		
No. 219	264.0	139.0	131.5	81.5	69.1	38.0	50.2
No. 220	262.0	129.0	119.0	74.0	71.8	37.8	54.6
Mean of 3					**70.3**± .437		
Mean of 5					**70.3**± .274	**37.5**± .209	**52.4**± .437
Error of 1					± .612		

SECTION J.—FIELD-CURED RED AMBER SORGHUM COLLECTED AT AMARILLO, TEX.

[Dates of weighing: Original material, Nov. 9; intermediate, Dec. 5; air-dry material, Dec. 16.]

No. 221	42	40.0	31.0	24.0	42.9	22.6	26.0
No. 222	35	33.0	24.0	17.0	51.4	29.2	31.4
No. 223	37	34.0	25.0	18.5	50.0	26.0	32.4
Mean of 3					**48.1**±1.450		
No. 224	40	37.0	27.5	21.0	47.5	23.6	31.2
No. 225	38	35.0	26.0	19.0	50.0	26.9	31.6
Mean of 3					**49.2**± .459		
Mean of 5					**48.4**± .812	**25.5**±0.712	**30.5**±0.694
Error of 1					±1.816		
No. 226	67	61.0	52.5	35.5	47.0	32.4	21.6
No. 227	69	64.0	54.0	36.5	47.1	32.4	21.7
No. 228	70	64.0	54.5	38.5	45.0	29.4	22.1
Mean of 3					**46.4**± .377		
No. 229	70	64.0	54.0	38.0	45.7	29.6	22.9
No. 230	72	67.0	58.0	44.5	38.2	23.3	19.4
Mean of 3					**43.0**±1.317		
Mean of 5					**44.6**± .987	**29.3**±1.003	**21.5**± .351
Error of 1					±2.221		
No. 231	105	98.0	87.5	62.0	41.0	29.1	16.7
No. 232	104	96.0	85.5	62.5	40.0	26.9	17.8
No. 233	102	96.0	85.5	60.5	40.7	29.2	16.2
Mean of 3					**40.6**± .163		
No. 234	104	97.0	88.5	60.5	41.8	31.6	15.0
No. 235	106	100.0	88.0	60.5	42.9	31.3	17.0
Mean of 3					**41.8**± .349		
Mean of 5					**41.3**± .300	**29.7**± .515	**16.5**± .281
Error of 1					± .671		
No. 236	133	125.0	113.5	82.0	38.3	27.8	14.7
No. 237	135	127.0	116.0	79.5	41.1	31.5	14.1
No. 238	134	126.0	116.5	86.0	35.8	26.2	13.1
Mean of 3					**38.4**± .842		
No. 239	134	128.0	118.0	82.0	38.8	30.5	12.0
No. 240	134	124.0	115.0	84.0	37.3	27.0	14.2
Mean of 3					**37.3**± .477		
Mean of 5					**38.3**± .528	**28.6**± .617	**13.6**± .290
Error of 1					±1.182		

RELIABILITY OF AIR-DRIED SAMPLES.

The reliability of air-dried samples may be determined in three ways: (1) By a comparison of the percentages of moisture loss in the samples with that in the 100-pound and 500-pound quantities, which, on account of their bulk, approximate field methods; (2) by a careful comparison of the relation between the moisture lost in air drying and the total moisture content as revealed by oven drying; and (3) by noting the variation in the percentage of moisture remaining in the air-dried material. A comparison of the moisture loss in air-dried samples with that in bulk lots of the same material is given in Table II.

TABLE II.—*Comparison of the loss of moisture in green and field-cured forage when air dried in small samples and in large bulk.*

Place.	Crop.	Moisture in green material.			Moisture in field-cured material.		
		Total.	Loss in samples.	Loss in bulk.	Total.	Loss in samples.	Loss in bulk.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Chico, Cal	Alfalfa	76.9	74.5	73.0	22.3	14.3	11.5
Arlington Farm, Va	Tall oat-grass and orchard grass.	72.0	66.3	64.3	29.0	13.4	13.5
New London, Ohio	Timothy	58.0	50.5	49.2	20.3	7.2	10.1
Amarillo, Tex	Sorghum	71.2	54.2	58.2	43.2	20.5	16.8
Hays, Kans	do	.....	65.8	60.9	.....	26.0	22.1

It will be seen that the losses in the small samples of green material, except for those of sorghum at Amarillo, Tex., which were not well cured, averaged from 1.3 to 4.9 per cent greater than it did in the bulk lots. This was to be expected, since the small sample naturally dries out more completely than the bulk. The difference, however, is slight, and the loss of moisture in the small samples seems to be fairly consistent with the loss which was found in the bulk lots.

The comparison of small samples with bulk lots of field-cured material is not so favorable to the use of the sample method as in the case of the green material. Table II also shows that the moisture loss in the samples, when compared with the total moisture content, is not quite so consistent as the percentage of moisture loss in the bulk lots.

A better way to determine the reliability of the sample method is by a study of the percentages themselves, especially in the column devoted to percentage of moisture in the air-dry material. The uniformity of these percentages throughout one crop means that the air drying of samples can be depended upon to bring samples to a nearly uniform moisture content, and this method therefore serves the purpose of correcting field weights almost as well as to oven dry the samples. The moisture content of the air-dry samples is not en-

tirely uniform, but except in a few instances the probable error is quite low, averaging for over 200 samples only 0.28 of 1 per cent. With such a low probable error it seems entirely reasonable to depend upon the air drying of samples for all practical purposes.

COMPARISON OF SAMPLES OF GREEN FORAGE WITH SAMPLES OF FIELD-CURED FORAGE.

Summary Table III gives a complete comparison of the averages of the probable error in green and field-cured samples for the different crops as collected by six individuals. These averages include more than 250 samples of green material and more than 200 samples of field-cured material. The best index to the reliability of these samples is in the percentage of moisture in the original samples.

TABLE III.—*Mean percentages of moisture in forage samples of different sizes, showing also probable errors.*

SECTION A.—GREEN MATERIAL.[1]

Sample.	Crop.	Place.	Moisture.		
			Original samples.	Air dry.	Lost in air drying.
			Per cent.	*Per cent.*	*Per cent.*
4-pound	Sorghum..	Amarillo, Tex.	73.2±0.516	34.8±0.894	58.9±0.801
8-pound	...do.....	.....do.....	71.2± .248	37.9± .630	53.7± .643
12-pound	...do.....	.....do.....	70.1± .451	38.1± .476	51.6± .523
16-pound	...do.....	.....do.....	70.3± .274	37.5± .209	52.4± .437
Mean			**71.2**	**37.1**	**54.2**
4-pound	Sorghum..	Hays, Kans ..	.....	.....	66.9± .526
8-pound	...do.....	.....do.....	.....	.....	68.0± .296
12-pound	...do.....	.....do.....	.....	.....	64.9± .289
16-pound	...do.....	.....do.....	.....	.....	63.4± .393
Mean			.....	.....	**65.8**
4-pound	Timothy..	New London, Ohio.	58.1± .204	15.0± .192	50.6± .272
8-pound	...do.....	.....do.....	57.8± .310	15.3± .070	50.2± .359
12-pound	...do.....	.....do.....	57.8± .137	15.0± .176	50.5± .230
16-pound	...do.....	.....do.....	58.4± .167	15.4± .179	50.8± .194
Mean			**58.0**	**15.2**	**50.5**
4-pound	Tall oat-grass.	Arlington, Va.	71.1± .203	15.8± .095	65.9± .129
8-pound	...do.....	.....do.....	71.5± .268	17.4± .145	65.5± .353
12-pound	...do.....	.....do.....	72.2± .056	17.5± .157	66.3± .060
16-pound	...do.....	.....do.....	73.3± .355	17.6± .079	67.5± .424
Mean			**72.0**	**17.1**	**66.3**
4-pound	Alfalfa....	Arlington, Va.	74.0± .344	10.7± .517	71.0± .237
8-pound	...do.....	.....do.....	74.8± .225	10.5± .129	71.8± .257
12-pound	...do.....	.....do.....	75.5± .160	10.9± .107	72.5± .136
16-pound	...do.....	.....do.....	76.5± .155	10.8± .251	73.6± .155
Mean			**75.2**	**10.7**	**72.2**
4-pound	Alfalfa....	Chico, Cal.....	75.1± .258	7.6± .253	73.0± .249
8-pound	...do.....	.....do.....	76.7± .234	9.8± .407	74.2± .258
12-pound	...do.....	.....do.....	77.7± .129	10.3± .113	75.2± .144
16-pound	...do.....	.....do.....	78.0± .109	10.2± .098	75.4± .108
Mean			**76.9**	**9.5**	**74.5**

[1] Average probable error for the 4-pound samples, 0.305; for the 8-pound, 0.257; for the 12-pound, 0.187; for the 16-pound, 0.212; and for all the samples, 0.240.

TABLE III.—*Mean percentages of moisture in forage samples of different sizes, showing also probable errors*—Continued.

SECTION B.—FIELD-CURED MATERIAL.[1]

Sample.	Crop.	Place.	Moisture.		
			Original samples.	Air dry.	Lost in air drying.
			Per cent.	*Per cent.*	*Per cent.*
2-pound	Sorghum..	Amarillo, Tex.	48.4±0.812	25.5±0.712	30.5±0.694
4-pound	...do.....	.....do.....	44.6± .987	29.3±1.003	21.5± .351
6-pound	...do.....	.....do.....	41.3± .300	29.7± .515	16.5± .281
8-pound	...do.....	.....do.....	38.3± .528	28.6± .617	13.6± .290
Mean			**43.2**	**28.3**	**20.5**
2-pound	Sorghum..	Hays, Kans...	.....	.....	26.9± .952
4-pound	...do.....	.....do.....	.....	.....	25.0± .432
6-pound	...do.....	.....do.....	.....	.....	26.9± .422
8-pound	...do.....	.....do.....	.....	.....	25.0± .302
Mean			.....	.....	**26.0**
2-pound	Timothy..	New London, Ohio.	18.8± .254	13.8± .192	5.3± .402
4-pound	...do.....	.....do.....	20.7± .321	14.2± .224	7.6± .384
6-pound	...do.....	.....do.....	21.7± .285	14.3± .148	8.6± .388
8-pound	...do.....	.....do.....	20.1± .277	14.0± .127	7.1± .354
Mean			**20.3**	**14.1**	**7.2**
2-pound	Tall oat-grass.	Arlington, Va.	31.8± .409	17.7± .295	17.1± .418
4-pound	...do.....	.....do.....	29.2± .750	19.9± .861	14.1± .863
6-pound	...do.....	.....do.....	27.8± .522	17.3± .112	12.7± .566
8-pound	...do.....	.....do.....	27.2± .136	19.4± .113	9.5± .169
Mean			**29.0**	**18.6**	**13.4**
2-pound	Alfalfa....	Arlington, Va.[2]	9.0± .193	9.5± .045	.....
4-pound	...do.....	.....do.....	10.4± .099	10.0± .203	.....
6-pound	...do.....	.....do.....	12.3± .257	9.4± .156	.....
8-pound	...do.....	.....do.....	12.0± .181	11.0± .135	.....
Mean			.....	**10.0**	.....
2-pound	Alfalfa....	Chico, Cal.....	20.6± .558	8.6± .587	13.2± .611
4-pound	...do.....	.....do.....	23.9± .585	9.7± .095	15.9± .548
6-pound	...do.....	.....do.....	22.4± .399	9.3± .067	14.6± .452
8-pound	...do.....	.....do.....	22.4±1.454	11.5± .186	13.4± .089
Mean			**22.3**	**9.8**	**14.3**

[1] Average probable error for the 2-pound samples, 0.445; for the 4-pound, 0.548; for the 6-pound, 0.353; for the 8-pound, 0.515; and for all the samples, 0.465.

[2] The alfalfa at Arlington was cured in the greenhouse before the original weight was taken, so that the original weight is of air-dry rather than of field-cured material.

The average probable error for the green samples is about 0.240 of 1 per cent, and of the field-cured samples 0.465 of 1 per cent. It appears from this that the probable error for green samples is approximately half that found in the corresponding field-cured samples. In field practice, however, this difference is not so important as it appears, because the bulk on which the correction is made in the field-cured material is approximately half of that where the original green weight is considered.

Much greater extremes, however, are found in the field-cured samples than in the green samples, showing that even though the average probable error is not excessive, still there is a possibility of sufficient error in these to affect the results when corrections are

made with only one sample. Table II also shows that the samples of field-cured material are less consistent than samples of green material when compared with bulk lots of the same forage dried under similar conditions.

RELATIVE VALUE OF SAMPLES OF DIFFERENT SIZES.

The figures on the relative value of samples of different sizes as given in Table III are not conclusive. There is a general, though not consistent, decrease in the probable error as the size of the sample is increased, but what would otherwise have been an expressive array of averages has been spoiled by the excessive probable error in the 8-pound field-cured sample of alfalfa at Chico, Cal. The average probable error for the 8-pound samples, including the Chico results, is 0.515 per cent; if we eliminate the Chico results it would be 0.281 per cent, which perhaps is nearer what might ordinarily be expected. It will be noted that as the green samples of alfalfa and of tall oat-grass increase in size, the greater was the percentage of loss in curing, as indicated by the column headed "Moisture in original samples" in Table III. This fact makes it seem probable that there was a loss, by fermentation, of matter other than water, but such a loss would not mean an increase of error in the use of samples when the samples are of a uniform size.

On account of the difficulty of curing samples of green forage they must necessarily be comparatively small, and when used in correcting actual field weights the samples, whether green or field cured, must be small enough to admit of easy handling. From the data presented in the table, it seems that the 4-pound field-cured and the 8-pound green samples are nearly as accurate as the larger ones. Considering accuracy, the facility of handling, the ease of figuring percentages, etc., 5-pound samples of field-cured and 10-pound samples of green material are recommended as the most desirable for practical work.

EFFECT OF REPLICATING THE SAMPLES.

The data on the effect of replicating the samples are found in Table IV, where the probable error has been expressed for single samples, replicates of three, and replicates of five and six.

TABLE IV.—*Average of the probable errors of one, three, and five or six samples.*

Number of replications.	Field-cured material.					Green material.					Grand average.
	2-pound.	4-pound.	6-pound.	8-pound.	Average.	4-pound.	8-pound.	12-pound.	16-pound.	Average.	
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
One	1.006	1.243	0.818	0.994	1.015	0.686	0.586	0.407	0.486	0.527	0.777
Three	.458	.668	.397	.473	.499	.331	.277	.156	.256	.255	.377
Five and six	.445	.548	353	.515	.465	.278	.257	.187	.212	.234	.349

Extreme care in sampling has kept the probable error very low on the single sample, so that it is nowhere excessive, but replicating the sample three times reduces the probable error 51.5 per cent, while a replication five and six times reduces the probable error over single samples 55.1 per cent and over three replications only 7.4 per cent. It does not seem necessary, therefore, in practice to replicate more than three times. Single samples, however, can not be considered safe when there is wide variation within the plat unless extreme care is used to make the sample composite and representative of the entire area.

MOISTURE PERCENTAGES IN GREEN FORAGE AND IN FIELD-CURED FORAGE, AS SHOWN BY SAMPLES.

Farrell, in an article in the American Journal of Agronomy,[1] suggests the desirability of expressing alfalfa-hay yields in terms of green weight. In the article referred to above, he reports 76.5 per cent of moisture lost in air drying, which would be approximately equivalent to 79.5 per cent of total moisture. The average percentage of moisture in the 23 analyses of green alfalfa reported by Jenkins and Winton [2] was 71.8.

At Arlington Farm, Va., green alfalfa averaged 75.2 per cent of moisture in 20 samples. This percentage is probably near the average for moderately thrifty alfalfa grown without irrigation in the Central and Eastern States. Alfalfa grown under irrigation and cut when one-tenth in bloom at Chico, Cal., averaged in 1914, 76.9 per cent of moisture. In 1911 McKee [3] found at this station as the average of 28 determinations in alfalfa not quite in bloom 85.8 per cent of moisture. The 1914 results indicate that the condition of growth affects the moisture content very decidedly. Owing to excessive heat and scarcity of water, the alfalfa used for the 1914 samples was less vigorous than that of 1911 and correspondingly less succulent. These differences indicate very clearly the danger of basing yields on the green weight, as suggested by Farrell, or of using some arbitrary percentage of moisture in making corrections on the green weight. Samples should always be taken in experimental work when the crop is harvested and the amount of moisture in the forage at that time determined from them. Field-cured alfalfa at Chico in 1914 had 22.3 per cent of moisture, while Jenkins and Winton [2] report as the average of 21 analyses only 8.4 per cent. The samples of Jenkins and Winton had probably dried out to some extent after being brought into the laboratory.

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[1] Farrell, F. D. Basing alfalfa yields on green weights. *In* Jour. Amer. Soc. Agron., v. 6, no. 1, p. 42–45, 1914.

[2] Jenkins, E. H., and Winton, A. L. A compilation of analyses of American feeding stuffs. U. S. Dept. Agr., Office Exp. Stas. Bul. 11, p. 22–75, 1892.

[3] McKee, Roland. Arabian alfalfa. *In* U. S. Dept. Agr., Bur. Plant Indus. Cir. 119, p. 25–30, 1913.

The bulk of the timothy samples taken at New London, Ohio, in 1914 were overmature for hay, being past bloom and with many of the lower leaves dead. In this condition the green timothy contained only 58 per cent of moisture, but when cut at the proper time (in bloom) it contained 71.4 per cent. The timothy which contained 58 per cent of moisture when green contained 20.3 per cent when field cured. Jenkins and Winton [1] report an average of 61.6 per cent of moisture for green timothy and 13.2 per cent for field cured.

Meadow hay at Arlington Farm, Va., containing a mixture of tall oat-grass and orchard grass had when green 72 per cent and when field cured 29 per cent of moisture. Although the field-cured samples were taken after the hay had dried sufficiently so that moisture could not be wrung from the stems by twisting a bunch of hay in the hands, still it was adjudged not quite dry enough to stack.

Red Amber sorghum in fairly thrifty condition at Amarillo, Tex., had 71.2 per cent of moisture when green and 43.2 per cent when field cured. The percentage of moisture, though about the same as that of other crops for the green material, was much higher in the field-cured state. Undoubtedly this was due to the moisture carried in the stems. Jenkins and Winton [1] report 79.4 per cent of moisture in green sorghum, but give no figures for the field-cured material. In corn, however, which should be much the same as sorghum, the average of 126 analyses of green material showed 79.3 per cent of moisture, while 35 analyses of field-cured material gave an average of 42.2 per cent of moisture.

These results go to show that forage crops when ready to harvest average about 70 to 80 per cent of moisture in the fresh material. Field-cured material of different crops varies so widely in moisture content that the percentage to be expected in any one case can hardly be foretold.

MOISTURE LOST IN AIR DRYING SAMPLES.

Consideration of the means in Table III shows that irrigated alfalfa at Chico, Cal., lost in air drying 74.5 per cent of moisture out of a total of 76.9 per cent. Unirrigated alfalfa at Arlington Farm, Va., lost 72.2 per cent out of a total of 75.2 per cent. Timothy at New London, Ohio, lost 50.5 per cent out of a total moisture content of 58 per cent, but, as shown in Table VI, the loss was 68.8 per cent when the total moisture content was 71.4 per cent; the mixture of tall oat-grass and orchard grass at Arlington Farm, Va., lost 66.3 per cent out of a total of 72 per cent; and the Red Amber sorghum at Amarillo lost 54.2 per cent out of a total of 71.2 per cent. At Hays, Kans., sorghum lost 65.8 per cent in air drying. This difference is no doubt due to the fact that the stems of the sorghum

[1] Jenkins, E. H., and Winton, A. L. Op. cit.

were split in the Hays samples, while in the Amarillo samples the stems were left entire. Splitting the stems when collecting sorghum samples greatly accelerates air drying and probably adds to the uniformity of the dried samples. This practice is recommended in the preparation of sorghum samples for correcting yields.

AMOUNT OF MOISTURE IN AIR-DRY SAMPLES.

The amount of moisture in the air-dry material depends not only upon the humidity of the atmosphere but also on the nature of the material in the sample. The sorghums, unless allowed to remain an extraordinary time under conditions suited for drying, retain a considerable percentage of moisture because of their large stems with the hard outer walls. Alfalfa, on the other hand, being quite succulent and leafy, loses its moisture rapidly and rather completely. Alfalfa at Chico had 9.7 per cent of moisture in the air-dried material, while at Arlington Farm, Va., there was 10.4 per cent. This difference probably represents the effect of the different degrees of humidity at the two places.

Timothy at New London, Ohio, retained 14.7 per cent of moisture in the air-dried material, while the mixture of tall oat-grass and orchard grass at Arlington Farm, Va., retained 17.9 per cent. Sorghum at Amarillo, where the stems were not split in the samples, retained an average of 32.7 per cent. It is unfortunate that dry-matter determinations were not made on the samples collected at Hays, Kans., as this would have given an opportunity to compare with the Amarillo samples others in which the stems were split and the drying was much more complete.

The above percentages no doubt represent fairly accurately the moisture percentages which may be expected in the air-dry samples of these different crops.

EFFECTS OF DRYING SAMPLES IN THE SUN AND IN THE SHADE.

To compare the relative moisture content of air-dry material allowed to cure in the shade with that cured in the direct sunshine, two sets of alfalfa samples were taken at Chico, Cal., and two sets of the mixture of tall oat-grass and orchard grass were prepared at Arlington Farm, Va., one set at each station being placed in the shade to cure, while the corresponding set was cured in the sun. The results, as given in Table V, show that while the total shrinkage was greater in the shade-cured samples at both places the moisture content of the air-dry material was a little less in the sun-cured samples at Chico and a little greater in those cured in the same way at Arlington Farm.

TABLE V.—*Comparison of sun-dried and shade-dried samples of green material of alfalfa and of a mixture of tall oat-grass and orchard grass.*

Place.	Crop.	Treatment.	Moisture, original material.	Moisture, air-dry material.	Moisture lost in air drying.
			Per cent.	*Per cent.*	*Per cent.*
Arlington Farm, Va....	Tall oat-grass and orchard grass.	Cured in shade..	71.5±0.268	17.4±0.145	65.5±0.353
Do.....	.....do.....	Cured in sun....	70.8± .391	19.8± .204	63.5± .558
Chico, Cal.[1].....	Alfalfa.....	Cured in shade..	75.9± .267	11.6± .486	72.7± .314
Do.[1].....	.....do.....	Cured in sun....	74.0± .061	10.7± .180	70.8± .120

[1] The detailed record of these samples is given in Table XII. Samples 549, 550, 551, 554, 555, 556, and 557 were cured in the shade; Nos. 552, 553, 559, and 560 were cured in the sun.

The differences indicated in Table V are too small to warrant any conclusions, even if the results at the two stations agreed. It would seem, therefore, that so far as the moisture content of the air-dry material is concerned it makes little difference whether the samples are dried in the sun or in the shade. The greater shrinkage in the shade-dried samples was perhaps due to loss of dry material on account of fermentation, which might well be greater in green material dried in the shade than that dried in the sun on account of the more favorable conditions for the development of fermentation organisms.

VALUE OF CORRECTING FIELD WEIGHTS BY THE SAMPLE METHOD.

The work so far done in correcting forage yields by samples makes it apparent that the method is of greatest importance with crops that lose their moisture slowly, such as the sorghums and Sudan grass. It is also valuable in comparative work where the treatment accorded different plats of the same crop differs widely, or in a comparison of varieties that lose moisture at different rates. The use of this method of correcting yields by samples, if it should become general, would be of much value in standardizing agronomic data obtained in different countries and different parts of the United States, where conditions affecting a crop during the growing and harvesting period differ greatly.

The use of the sample method and the differences which may be expected from corrections made in this way are well illustrated by the following results obtained on the forage-crop field stations in the regular plat work.

Sorghum.—At Chico, Cal., the corrected weight of sorghum, as determined by the use of air-dried samples, was 41.6 to 47 per cent less than the weights taken in the field at the time of stacking the crop. This fodder was not as dry at the time of taking the field weights as is desirable, yet it may fairly have been called field cured in the ordinary meaning of the term. At Hays, Kans., the corrected weights, as computed from air-dried samples, average 20 to 30 per cent

lower than the field weights, even when the sorghum had been curing through seven weeks of good drying weather after harvest. The differences in field-cured and computed air-dry weights for different varieties and different dates of planting varied from minus 3.7 per cent to plus 31.3 per cent. It would seem, therefore, that maturity at harvest, size of shock, and succulence of the variety are factors affecting the moisture content of field-cured sorghum almost as much as different lengths of drying periods. At Amarillo, Tex., the difference in the percentage of moisture in field-cured material of Red Amber sorghum and air-dry samples of the same varied from 12 to 33 per cent, while the total moisture in the samples varied from 35.8 to 55.7 per cent, as determined by oven drying. Such differences are enough in many instances to change the conclusions of the value of different methods of treatment or different dates of planting.

Sudan grass.—At Hays, Kans., after Sudan grass had been cured three days, the field weights were 25 to 40 per cent greater than the computed air-dry weights based on samples, and there was 21 to 40 per cent difference after a similar period of curing at Chillicothe, Tex. Many of the phenomenal yields of Sudan grass and sorghum that are reported by newspapers can be explained in part by this excessive moisture content.

Alfalfa.—The computed air-dry weights of alfalfa at Chico, Cal., were 10 to 15 per cent less than the field-cured weights, while at Hays, Kans., in good curing weather, there was a difference of only 2 per cent.

Different methods of culture affect the moisture content quite decidedly, as shown with alfalfa at Chico, where in the May 15 cutting the hay from drilled plats showed only 10.9 per cent loss in air drying, while in the 35-inch rows the loss was 24.3 per cent. Cuttings of alfalfa made at different stages of maturity can not be compared accurately unless they are checked by the sample method. The difference in moisture content of the field-cured material has been found in a number of instances to be as great as 30 per cent.

Millet.—Of all the crops tested, millet showed the least difference between the air-dried and the field-cured material. The loss at Hays, Kans., averaged about 9.3 per cent.

RELATION OF THE STAGE OF GROWTH OF FORAGE PLANTS TO THEIR MOISTURE CONTENT.

It has long been known that plants when young contain a larger percentage of water than they do when mature, but no great amount of data on this point, even for our principal crop plants, is to be found. A compilation[1] of all the data available on this subject indicates the average percentage of moisture in alfalfa to be as follows:

[1] Vinall, H. N., and McKee, Roland. A digest of literature relating to the moisture content and shrinkage of forage. *In* Jour. Amer. Soc. Agron., v. 8, no. 2, 1916.

Height of 18 inches, 83.3; in bud, 79.1; early bloom, 77.8; half in bloom, 74.3; in full bloom, 70.6; bloom fading, 68.3; leaves drying, 65.1; fully ripe, 55.9. For timothy: Heads not yet visible, 74.4; heads just appearing, 72.9; heads fully out, 70.8; beginning to bloom, 66.7; in full bloom, 64.3; past bloom, 59.8; seed fully formed, 54.3; seed becoming hard, 49.2.

Investigations on this point were made with the following crops: At Chico, Cal., alfalfa; at Hays, Kans., and Amarillo, Tex., sorghum; and at New London, Ohio, timothy. In the alfalfa several cuttings were made at intervals early in the season, so that later all the different stages of maturity could be secured on the same date. The same result was accomplished in the annuals by using plats of sorghum which were planted at different dates. The intention was to handle the timothy in the same way as the alfalfa, but such arrangements were found impossible, and the cuttings of timothy were made on different dates. Samples of all these crops were secured, representing approximately the following stages of development:

(*a*) Very young, intermediate between the beginning of growth and budding.
(*b*) In bud, before bloom began.
(*c*) About one-tenth in bloom.
(*d*) Full bloom.
(*e*) Fully mature, seed hardening.

Eight-pound samples representing each stage of development were taken immediately after cutting. Each sample was placed in a sack and kept for 20 days or more until it became perfectly air dry. The amount of moisture lost in air drying was then determined and the sample was sent to Washington, D. C., where it was reduced to a water-free basis in the drying oven. The results obtained with the different crops are given in Table VI, the averages for each crop being also set forth in a separate summary (Table VII).

TABLE VI.—*Moisture in growing forage at different stages of development and in the air-dry material.*

SECTION A.—ALFALFA SAMPLES COLLECTED AT CHICO, CAL.

[Dates of weighing: Original material, July 2; intermediate, Aug. 19; air-dry material, Aug. 24.]

Sample and stage of growth.	Weight.				Moisture.		
	Green.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
Very young; 12 inches high:	*Ounces.*	*Ounces.*	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*
No. 586	123.2	27.95	27.95	24.0	80.5	14.1	77.3
No. 587	123.2	29.45	29.45	26.0	79.0	11.8	76.1
No. 588	123.2	31.70	31.95	28.0	77.3	12.3	74.1
No. 589	123.2	31.45	31.45	28.0	77.3	11.1	74.5
No. 590	123.2	27.95	28.20	24.5	80.2	13.1	77.1
Average					**78.9±0.412**	**12.5±0.314**	**75.8±0.395**

TABLE VI.—*Moisture in growing forage at different stages of development, etc.*—Cont'd.

SECTION A.—ALFALFA SAMPLES COLLECTED AT CHICO, CAL.—Continued.

Sample and stage of growth.	Weight.				Moisture.		
	Green.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
One-tenth bloom:	*Ounces.*	*Ounces.*	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*
No. 581	123.2	30.95	30.95	26.0	78.9	16.0	74.9
No. 582	123.2	32.20	31.95	28.5	76.9	10.7	74.2
No. 583	123.2	30.95	30.95	27.5	77.7	11.1	74.9
No. 584	123.2	34.70	34.20	31.0	74.8	9.2	72.3
No. 585	123.2	31.95	31.70	28.0	77.3	11.6	74.3
Average					**77.1± .393**	**11.7± .689**	**74.1± .289**
Full bloom:							
No. 576	123.2	35.45	35.20	31.5	74.4	10.5	71.5
No. 577	123.2	35.45	35.45	31.5	74.4	11.2	71.2
No. 578	123.2	35.20	34.95	31.0	74.8	11.2	71.6
No. 579	123.2	34.70	34.95	31.0	74.8	11.2	71.6
No. 580	123.2	35.45	35.20	31.0	74.8	11.8	71.5
Average					**74.6± .060**	**11.2± .124**	**71.5± .045**
Past full bloom:							
No. 571	123.2	38.20	37.95	33.5	72.8	11.7	69.2
No. 572	123.2	37.45	36.95	33.0	73.2	10.6	70.0
No. 573	123.2	35.95	35.70	31.5	74.5	11.8	71.0
No. 574	123.2	36.70	36.70	32.5	73.7	11.5	70.2
No. 575	123.2	37.95	37.70	33.5	72.9	11.2	69.5
Average					**73.4± .188**	**11.4± .131**	**70.0± .188**

SECTION B.—SORGHUM SAMPLES COLLECTED AT AMARILLO, TEX.

[Dates of weighing: Original material, Aug. 17; intermediate, Nov. 2; air-dry material, Dec. 17.]

Very young:							
No. 241	135	25	15.5	13.0	90.4	16.1	88.5
No. 242	136	30	15.0	11.5	91.5	23.3	89.0
No. 243	134	25	15.0	13.0	90.3	13.3	88.8
No. 244	138	23	15.0	13.0	90.6	13.3	89.1
No. 245	135	24	15.0	13.0	90.4	13.3	88.9
Average					**90.6±0.134**	**15.9±1.169**	**88.9±0.063**
Heads in boot:							
No. 246	139	40	27.0	19.0	86.3	29.6	80.6
No. 247	138	39	24.0	18.0	87.0	25.0	82.6
No. 248	138	36	22.0	17.0	87.7	22.7	84.1
No. 249	140	39	25.0	18.0	87.1	28.0	82.1
No. 250	140	38	24.0	17.5	87.5	27.1	82.9
Average					**87.1± .146**	**26.5± .725**	**82.5± .347**
Beginning to head:							
No. 251	135	40	28.0	20.0	85.2	28.6	79.3
No. 252	113	42	29.0	21.5	84.0	25.9	78.4
No. 253	134	39	27.0	21.0	84.9	22.2	80.6
No. 254	389	41	29.0	21.0	84.8	27.6	79.0
No. 255	140	40	28.0	21.0	85.0	25.0	80.0
Average					**84.8± .124**	**25.9± .670**	**79.5± .232**
Heads in bloom:							
No. 256	138	48	34.5	26.0	81.2	24.6	75.0
No. 257	138	48	35.0	26.0	81.2	25.7	74.6
No. 258	138	49	35.5	28.0	79.7	21.1	74.3
No. 259	139	47	34.5	27.5	80.2	20.3	75.2
No. 260	138	47	35.5	28.0	79.7	21.1	74.3
Average					**80.4± .204**	**22.6± .652**	**74.7± .111**
Ripe:							
No. 261	132	58	43.5	34.0	74.3	21.8	67.0
No. 262	136	59	45.5	33.0	75.7	27.5	66.5
No. 263	135	59	44.0	33.0	75.6	25.0	67.4
No. 264	135	58	42.5	33.0	75.6	22.4	68.5
No. 265	141	62	46.0	35.0	75.2	23.9	67.4
Average					**75.3± .157**	**24.1± .612**	**67.4± .199**

TABLE VI.—*Moisture in growing forage at different stages of development, etc.*—Cont'd.

SECTION C.—SORGHUM SAMPLES COLLECTED AT HAYS, KANS.

[Dates of weighing: Original material, Aug. 18; intermediate, Sept. 21; air-dry material, Sept. 27.]

Sample and stage of growth.	Weight.				Moisture.		
	Green.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
Very young:	*Ounces.*	*Ounces.*	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*
No. 301	154.00	23.00	18.50	15.25	91.0	17.5	88.0
No. 302	159.50	27.50	20.50	17.25	89.2	15.8	87.1
No. 303	141.25	24.25	20.75	17.75	87.4	14.4	85.3
No. 304	150.00	23.00	19.00	16.25	89.3	15.0	87.3
No. 305	147.50	23.50	19.00	16.25	89.0	14.4	87.1
Average					**89.2** ±0.344	**15.4** ±0.349	**87.0** ±0.270
Bloom:							
No. 306	146.75	31.75	25.75	21.50	85.3	16.5	82.6
No. 307	134.25	29.25	24.75	20.75	84.5	16.0	81.6
No. 308	143.75	30.75	26.25	23.25	83.8	11.5	81.7
No. 309	150.25	34.25	27.75	23.25	85.0	16.1	81.6
No. 310	157.50	33.50	30.50	25.50	83.8	16.3	80.6
Average					**84.5** ± .185	**15.3** ± .572	**81.6** ± .192
Soft dough:							
No. 311	150.25	38.25	28.75	24.75	83.5	13.8	80.9
No. 312	140 50	37.00	31.50	26.50	81.4	16.0	77.6
No. 313	157.50	37.50	34.50	29.25	81.4	15.1	78.1
No. 314	151.75	39.75	35.75	30.00	80.2	16.0	76.4
No. 315	160.75	45.75	40.25	33.50	79.2	16.7	75.0
Average					**81.1** ± .434	**15.5** ± .302	**77.6** ± .593
Hard dough:							
No. 316	159.75	46.75	41.25	34.00	78.7	17.5	74.2
No. 317	166.75	57.75	38.25	32.75	81.4	14.4	77.1
No. 318	131.75	42.75	40.25	33.50	74.6	16.7	69.4
No. 319	149.75	46.75	43.75	36.50	75.6	16.5	70.8
No. 320	160.50	49.50	45.50	38.50	76.0	15.4	71.6
Average					**77.3** ± .746	**16.1** ± .326	**72.6** ± .823
Seed ripe:							
No. 321	151.00	54.00	42.2	36.75	75.7	13.0	72.1
No. 322	149.25	53.25	41.75	34.75	76.7	16.8	72.0
No. 323	139.25	50.25	48.75	39.75	71.5	18.5	65.0
No. 324	157.00	61.00	56.5	47.75	69.6	15.5	64.0
No. 325	141.50	49.50	46.5	38.75	72 6	16.7	67.1
Average					**73.2** ± .795	**16.1** ± .549	**68.0** ±1.033

SECTION D.—TIMOTHY SAMPLES COLLECTED AT NEW LONDON, OHIO.

[Dates of weighing: Original material, May 20 to July 20; intermediate, Sept. 2; air-dry material, Sept. 28.]

Very young, May 20, 10–12 inches high:							
No. 449	124	.....	31	28.0	77.5	9.6	75.0
Just heading:							
No. 450	138	37	35	32.5	76.5	7.1	74.6
No. 451	158	42	41	37.0	76.6	9.7	74.0
Average					**76.6** ±0.034	**8.4** ±0.620	**74.3** ±0.143
Early bloom, June 20:							
No. 452	137	44	43	39.0	71.6	9.3	68.6
No. 453	135	43	42	39.0	71.2	7.1	68.9
Average					**71.4** ± .095	**8.2** ± .525	**68.8** ± .076
Full bloom, June 26:							
No. 454	131	47	46	42.0	68.0	8.7	64.9
No. 455	132	51	49	44.5	66.3	9.1	62.9
Average					**67.2** ± .406	**8.9** ± .095	**63.9** ± .337
Leaves drying, July 7:							
No. 456	119	56	54	48.5	59.3	10.1	54.5
No. 457	127	62	60	53.5	57.9	10.8	52.8
Average					**58.6** ± .334	**10.5** ± .169	**53.7** ± .406
Seed mature, July 20:							
No. 458	131	75	70	64.0	51.2	8.5	46.6
No. 459	131	74	71	64.0	51.2	9.8	45.8
Average					**51.2** ± .000	**9.2** ± .311	**46.2** ± .191

These results, which agree fairly well with the averages for timothy and alfalfa cited on page 23, show a decided decrease in moisture percentage as the crop approaches maturity. This difference is least in alfalfa and greatest in timothy, although in sorghum it was also considerable. The exact relation of the three crops as regards the moisture content at different periods of their growth is not apparent, because the stage of maturity when samples were taken was not identical in the three crops. It is quite probable that the mature seed stage of timothy, when the moisture content reached the very lowest figure, 51.2 per cent, was relatively later in the life period of the crop than was the ripe stage in the sorghums. This may account partly for the rather decided difference in the amount of moisture contained by the two crops at this stage. It appears, however, that sorghum has an unusually high moisture content throughout its entire life period. The fact that the very young sorghum plant is approximately 90 per cent water, while the young timothy is only 77 per cent and the young alfalfa 79 per cent water, suggests one reason why cutting sorghum when it is very immature affects the feeding value of the resulting hay so much more seriously than a like treatment does timothy or alfalfa.

These results are more apparent in the summary (Table VII), where the averages are brought together so as to make comparisons easier.

TABLE VII.—*Summary of average percentages of moisture in sorghum, timothy, and alfalfa at different stages of growth.*

Place, crop, and stage of growth.	Moisture.		
	Original material.	Air-dry material.	Lost in air drying.
	Per cent.	*Per cent.*	*Per cent.*
Amarillo, Tex., Red Amber sorghum:			
Very young	90.6±0.134	15.9±1.169	88.9±0.063
Shooting for heads	87.1± .146	26.5± .725	82.5± .347
Beginning to head	84.8± .124	25.9± .670	79.5± .232
Full bloom	80.4± .204	22.6± .652	74.7± .111
Ripe	75.3± .157	24.1± .612	67.4± .199
Hays, Kans., Red Amber sorghum:			
Very young	89.2± .344	15.4± .349	87.0± .270
Bloom	84.5± .185	15.3± .572	81.6± .192
Soft dough	81.1± .434	15.5± .302	77.6± .593
Hard dough	77.3± .746	16.1± .326	72.6± .823
Ripe	73.2± .795	16.1± .549	68.0±1.033
New London, Ohio, timothy: [1]			
May 20	77.5	9.6	75.0
Very young, 12 inches high, June 8	76.6± .034	8.4± .620	74.3± .143
Early bloom, June 20	71.4± .095	8.2± .525	68.8± .076
Full bloom, June 26	67.2± .406	8.9± .095	63.9± .337
Leaves drying, July 7	58.6± .334	10.5± .165	53.7± .406
Seed mature, July 20	51.2± .000	9.2± .311	46.2± .191
Chico, Cal., alfalfa:			
Plants 12 inches high	78.9± .412	12.5± .314	75.8± .395
First bloom to one-tenth in bloom	77.1± .393	11.7± .689	74.1± .289
Full bloom	74.6± .060	11.2± .124	71.5± .045
Past full bloom	73.4± .188	11.4± .131	70.0± .188

[1] Only 1 sample taken on May 20; on other dates 2 samples were taken.

The effect of the stage of development on the amount of moisture remaining in the air-dry material, as shown in Table VII, is also a matter of interest. In the case of alfalfa at Chico, Cal., the young plants air dry contained a little more moisture than the older plants. At New London, Ohio, timothy showed practically no difference. Red Amber sorghum at Hays, Kans., showed no difference, while at Amarillo, Tex., the young plants contained decidedly less. The uniformity of the moisture content at Hays and the lack of uniformity at Amarillo (Table VI) is accounted for by the fact that at Hays the stems of each sample were split, thus allowing the complete drying of the mature samples, while at Amarillo the stems were not split, and the immature specimens dried out more completely than the mature ones.

LOSS OF MOISTURE IN FORAGE DURING THE EARLY STAGES OF CURING.

To determine the rate of loss of moisture in different crops during the period directly following the cutting in different localities and under different weather conditions, the following crops were used: At Arlington Farm, Va., alfalfa and a mixture of tall oat-grass and orchard grass; at Chico, Cal., alfalfa; at New London, Ohio, timothy; and at Hays, Kans., sorghum. The material was cut as quickly as possible and weighed immediately, using about 100 pounds green weight. This 100 pounds of green forage was placed on a canvas and weighed every 10 minutes through 1 hour, and every 30 minutes thereafter until 4 hours had elapsed. At Hays and New London determinations were made under both clear and partly cloudy conditions, but at Chico and Arlington Farm determinations were made for each crop under one condition only.

At Hays, Kans., the experiment was carried out with Red Amber sorghum in the soft-dough stage, and records of moisture loss were secured both for forage scattered as it would be in the swath, and also bunched, as it would be if raked into windrows. On August 18 the sky was partly cloudy, the wind was blowing but little, and the maximum temperature was 104° F. On September 25 the first weights were taken at 1.40 p. m., and the last at 5.40 p. m. The day was bright, with a gentle breeze and a maximum temperature of 82° F. Table VIII gives the rate of loss of moisture in these experiments.

The rate of loss was greatest in the scattered material, but the difference is not as great as one might expect. In the first 30 minutes the loss ranged from 1 to 2 per cent. The difference in the amount of moisture lost by the bunched and the scattered lots was 4.89 per cent on August 18 and 4 per cent on September 25. The greatest loss in 4 hours in the bunched lots was 8.2 per cent and in the scattered lots 13.1 per cent.

TABLE VIII.—*Rate of loss of moisture in Red Amber sorghum during the early stages of curing at Hays, Kans., in 1914.*

Time of weighing.	Time elapsed.	On August 18.				On September 25.			
		Bunched.		Scattered.		Bunched.		Scattered.	
		Weight.	Loss in weight.	Weight.	Loss in weight.	Weight.	Loss in weight.	Weight.	Loss in weight.
	Hr. m.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
1.45 p. m.	... ...	110.0	0	99.5	0	100.0	0	100.0	0
1.55 p. m.	... 10	109.5	.5	99.0	.5	99.5	.5	100.0	0
2.05 p. m.	... 20	109.0	.9	98.0	1.5	99.0	1.0	99.5	.5
2.15 p. m.	... 30	108.0	1.8	97.5	2.0	98.5	1.5	99.0	1.0
2.25 p. m.	... 40	107.5	2.3	97.0	2.5	98.5	1.5	98.0	2.0
2.35 p. m.	... 50	106.5	3.2	95.5	4.0	96.0	4.0	97.5	2.5
2.45 p. m.	1 ...	106.0	3.6	94.5	5.0	97.5	2.5	97.0	3.0
3.15 p. m.	1 30	104.5	5.0	93.5	6.0	97.0	3.0	96.0	4.0
3.45 p. m.	2 ...	104.0	5.5	90.5	9.0	96.5	3.5	95.0	5.0
4.15 p. m.	2 30	103.0	6.4	89.0	10.6	96.5	3.5	94.0	6.0
4.45 p. m.	3 ...	102.5	6.8	88.0	11.6	95.5	4.5	93.0	7.0
5.15 p. m.	3 30	102.0	7.3	87.0	12.6	95.5	4.5	92.0	8.0
5.45 p. m.	4 ...	101.0	8.2	86.5	13.1	95.0	5.0	91.0	9.0

The striking point to be noted in connection with Table VIII is the great difference in the rate of moisture loss between sorghum and alfalfa or timothy, as indicated in Tables VIII to XI, inclusive.

At New London, Ohio, determinations were made of the rate of loss of moisture in timothy cut when in full bloom on July 4 and again on July 6. The sky was partly cloudy on July 4 and the temperature was 76° F. at noon. On July 6 the sky was clear and the thermometer registered 80° F. at 11 o'clock a. m., 79° at 1 o'clock p. m., and 76° at 4 o'clock p. m. In each case the samples were scattered in drying.

TABLE IX.—*Rate of loss of moisture in timothy during the early stages of curing at New London, Ohio, in 1914.*

Time of weighing.	Time elapsed.	Weight.	Loss in weight.	Time of weighing.	Time elapsed.	Weight.	Loss in weight.
July 4:	*Hr. m.*	*Pounds.*	*Per cent.*	July 6:	*Hr. m.*	*Pounds.*	*Per cent.*
12.00 m.	.. ..	115	0	11.00 a. m.	.. ..	115	0
12.10 p. m.	.. 10	112	2.6	11.10 a. m.	.. 10	112	2.6
12.20 p. m.	.. 20	110	4.3	11.20 a. m.	.. 20	110	4.3
12.30 p. m.	.. 30	107	7.0	11.30 a. m.	.. 30	108	6.1
12.40 p. m.	.. 40	106	7.8	11.40 a. m.	.. 40	106	7.8
12.50 p. m.	.. 50	105	8.7	11.50 a. m.	.. 50	104	9.6
1.00 p. m.	1 ..	103	10.4	12.00 m.	1 ..	103	10.4
1.30 p. m.	1 30	99	13.9	12.30 p. m.	1 30	98	14.8
2.00 p. m.	2 ..	96	16.5	1.00 p. m.	2 ..	94	18.3
2.30 p. m.	2 30	92	20.0	1.30 p. m.	2 30	89	22.6
3.00 p. m.	3 ..	88	23.5	2.00 p. m.	3 ..	86	25.2
3.30 p. m.	3 30	85	26.1	2.30 p. m.	3 30	84	27.0
4.00 p. m.	4 ..	83	27.9	3.00 p. m.	4 ..	81	29.6
4.30 p. m.	4 30	80	30.4	3.30 p. m.	4 30	78	32.2
5.00 p. m.	5 ..	80	30.4	4.00 p. m.	5 ..	77	33.0

The data given in Table IX show that in the first 30 minutes after cutting on July 4 there was a loss of 7 per cent and on July 6 in the same time a loss of 6.1 per cent. In the first hour on both dates the loss was 10.4 per cent, and in 5 hours the loss was 30.4 per cent on

July 4 and 33 per cent on July 6. These results show the rate of moisture loss in timothy at New London, Ohio, to be very nearly the same as that of alfalfa and the mixture of tall oat-grass and orchard grass at Arlington Farm, Va. (Table X), where the atmospheric humidity and the temperatures are very similar to those at New London.

Determinations of the rate of loss of moisture in a mixture of tall oat-grass and orchard grass and in alfalfa during the early stages of curing were made at Arlington Farm, Va., on June 3 and on October 16, 1914, respectively. The data secured in this work are given in Table X.

TABLE X.—*Rate of loss of moisture in a mixture of tall oat-grass and orchard grass and in alfalfa during the early stages of curing at Arlington Farm, Va., in 1914.*

Tall oat-grass and orchard grass.				Alfalfa.			
Time of weighing.	Time elapsed.	Weight.	Loss in weight.	Time of weighing.	Time elapsed.	Weight.	Loss in weight.
June 3:	*Hr. m.*	*Pounds.*	*Per cent.*	Oct. 16:	*Hr. m.*	*Pounds.*	*Per cent.*
12.30 p. m.	.. ..	100.0	0	12.40 p. m.	.. ..	100.0	0
12.45 p. m.	.. 15	96.5	3.5	12.50 p. m.	.. 10	98.0	2.0
12.55 p. m.	.. 25	95.0	5.0	1.00 p. m.	.. 20	96.0	4.0
1.10 p. m.	.. 40	92.5	7.5	1.10 p. m.	.. 30	94.0	6.0
1.20 p. m.	.. 50	90.0	10.0	1.20 p. m.	.. 40	91.0	9.0
1.30 p. m.	1 ..	88.5	11.5	1.30 p. m.	.. 50	89.0	11.0
1.45 p. m.	1 15	86.0	14.0	1.40 p. m.	1 ..	86.0	14.0
2.15 p. m.	1 45	80.5	19.5	2.10 p. m.	1 30	81.0	19.0
2.45 p. m.	2 15	76.5	23.5	2.40 p. m.	2 ..	77.0	23.0
3.15 p. m.	2 45	73.0	27.0	3.20 p. m.	2 40	75.0	25.0
3.45 p. m.	3 15	70.0	30.0	3.40 p. m.	3 ..	72.5	27.5
4.15 p. m.	3 45	66.5	33.5	4.10 p. m.	3 30	69.5	30.5
				4.40 p. m.	4 ..	68.0	32.0

The afternoon of June 3 was bright and fairly free from cloudiness, with a maximum temperature of 82° F. Under these conditions the mixture of tall oat-grass and orchard grass which was scattered on a tarpaulin lost 5 per cent of its weight in the first 25 minutes, 11.5 per cent in 1 hour, and 33.5 per cent in 3 hours and 45 minutes after cutting. The weights were taken as quickly as possible and the material scattered each time as soon as the tarpaulin was lowered. It will be noted that the loss of moisture was quite rapid, exceeding slightly that of the timothy at New London, Ohio.

The afternoon of October 16 was partly cloudy, but very warm for that season, the maximum temperature for the day being 73° F. Alfalfa under these conditions lost 6 per cent of its weight in the first 30 minutes, 14 per cent in 1 hour, and 32 per cent in 4 hours after cutting. On a bright day and with the same temperature as that prevailing on June 3 it is probable that the loss of moisture would have exceeded that of the mixture of tall oat-grass and orchard grass.

Determinations of the rate of moisture loss in alfalfa at Chico, Cal., have been made during several years, and these results are given in Table XI. These data appeared in slightly different form in an earlier

publication by McKee,[1] who called attention at that time to the fact that because some varieties of alfalfa after cutting lose moisture more rapidly than others the field weights will be incomparable unless sufficient time has elapsed to insure a uniform moisture content.

TABLE XI.—*Rate of loss of moisture in alfalfa varieties during the early stages of curing, at Chico, Cal., in 1910, 1911, and 1912.*

Time of weighing.	Time elapsed.			Arabian.			Peruvian.			Ordinary.	
				Weight.		Loss in weight.	Weight.		Loss in weight.	Weight.	Loss in weight
	Days.	Hours.	Minutes.	Grams.	Pounds.		Grams.	Pounds.			
Test A:						*Per ct.*			*Per ct.*	*Grams.*	*Per ct.*
June 22, 1910				254.0		0	276.0		0	240.0	0
June 23, 1910		24		98.8		61.1	129.7		53.0	107.5	55.2
June 25, 1910		72		76.7		69.8	91.6		66.8	83.3	65.3
Test B:[1]											
June 9, 1911[2]—											
10.22 a. m.				400.0		0	400.0		0	400.0	0
11.52 a. m.		1	30	243.8		39.1	271.3		32.2	269.3	32.7
1.22 p. m.		3		174.3		56.4	212.3		46.9	205.8	48.6
4 p. m.		5	38	145.1		63.7	172.9		56.8	175.9	56.0
Sept. 27, 1911	110			83.6		79.1	83.3		79.2	82.5	79.4
Test C:											
June 9, 1911—											
9.07 a. m.					100	0		100	0		
11 a. m.		1	53		73	27.0		78	22.0		
2 p. m.		4	53		41	59.0		48	52.0		
4 p. m.		6	53		36	64.0		42	58.0		
June 12, 1911	3				24	76.0		24	76.0		
Aug. 8, 1911	60				22	78.0		22	78.0		
Test D:											
June 4, 1912—											
10 a. m.					100	0		100	0		
11 a. m.		1			78.5	22.5		83.5	16.5		
12 a. m.		2			60.5	39.5		65.5	34.5		
2 p. m.		4			34.5	65.5		31.5	68.5		
4 p. m.		6			26	74.0		24.5	75.5		

[1] The weights of test B are an average of two samples in each case. The leaves constituted 56.4 per cent of the weight in the Arabian variety, 52.5 per cent in the Peruvian, and 49.8 per cent in the ordinary.
[2] First weight was taken about five minutes after cutting.

These data indicate very clearly that the rate of loss during the first four or five hours at Chico, Cal., greatly exceeds the loss during a like period at Arlington Farm, Va. This is doubtless due to both the higher temperature and the lower humidity of the atmosphere at Chico, the loss during the first 1½ hours at Chico being nearly equal to that during the first 3 hours at Arlington Farm.

In connection with these results it is well to note that the weighings of alfalfa at Chico were made in the month of June, while those at Arlington Farm were made in October.

It is also interesting to note that in tests B and C the Arabian variety lost moisture faster for the first few hours after cutting than the Peruvian or the ordinary alfalfa, but that in the end it had practically the same percentage of dry matter. A high percentage of leaves is usually thought to indicate a high moisture content, but the Arabian has 6.6 per cent more leaves than the ordinary, and yet the total moisture content is about the same for the two varieties.

[1] McKee, Roland. Arabian alfalfa. *In* U. S. Dept. Agr., Bur. Plant Indus. Cir. 119, p. 25-30, 1913.

VARIATION IN THE MOISTURE CONTENT OF GROWING ALFALFA DURING A SINGLE DAY.

In order to determine whether a different percentage of moisture is to be expected in forage plants cut at different times of the day, five samples of alfalfa were cut at 8 o'clock in the forenoon and six samples at 3 o'clock in the afternoon. The alfalfa was in a fairly vigorous condition and about one-tenth in bloom. The day was warm and sunny. A detailed statement of the results with each sample is given in Table XII.

TABLE XII.—*Moisture content of growing alfalfa at 8 a. m. and at 3 p. m., at Chico, Cal., in 1914.*

Sample.	Weight.				Moisture.		
	Green, June 13.	June 30.	Air dry, July 27.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
Cut at 8 a. m.:	*Ounces.*	*Ounces.*	*Ounces.*	*Ounces.*	*Per cent.*	*Per cent.*	*Per cent.*
No. 549	123.2	33.70	31.95	28.5	76.9	10.7	74.1
No. 550	123.2	35.95	33.70	29.0	76.5	13.8	72.7
No. 551	123.2	35.70	32.45	29.5	76.1	9.1	73.7
No. 552	123.2	34.95	35.20	31.5	74.5	10.5	71.4
No. 553	123.2	34.95	34.95	31.5	74.5	9.7	71.6
Mean					**75.7±0.216**	**10.8±0.346**	**72.7±0.231**
Cut at 3 p. m.:							
No. 554	91.2	26.95	26.95	24.0	73.6	10.8	70.4
No. 555	91.2	26.45	25.70	22.5	75.3	12.2	71.8
No. 556	91.2	24.70	23.95	21.0	77.0	12.2	73.7
No. 557	91.2	26.20	25.70	22.5	75.3	12.3	71.8
No. 559	91.2	27.45	27.70	24.5	73.1	11.5	69.6
No. 560	91.2	26.70	26.95	24.0	73.6	10.8	70.4
Mean					**74.7± .263**	**11.6± .127**	**71.3± .261**

The mean for the two methods of treatment shows 1 per cent more moisture in the alfalfa at 8 a. m. than at 3 p. m. While this difference is not large, there is a sufficient number of samples so that the results are dependable. In actual practice this result has little significance, but it is of interest to find that in the open field under favorable moisture conditions transpiration may exceed the absorption of water by the roots sufficiently so that the moisture equilibrium in the plant tissues is not maintained.

MOISTURE CONTENT OF BALED HAY.

In order to give some idea of the amount of moisture in ordinary baled hay, samples were taken from oat hay in the bale at Chico, Cal., at two dates, the first about one month and the second about two months after the hay was baled. Ordinary commercial hay was used in this experiment, so the moisture percentage may be considered as fairly representative of that in the grain hays on the market in California. The moisture content, as determined by two sets of samples, is given in Table XIII.

TABLE XIII.—*Moisture content of baled oat hay and moisture lost in air drying at Chico, Cal., in 1914.*

Sample.	Weight.								Moisture.	
	July 1.	July 10.	July 20.	July 27.	Aug. 4.	Aug. 19.	Aug. 24.	Oven dry.	Original sample.	Lost in air drying.
	Ounces.	*Ounces.*	*Ounces.*	*Ounces.*	*Ounces.*	*Ounces.*	*Ounces.*	*Ounces.*	*Per ct.*	*Per ct.*
No. 561	44.5	43.00	43.25	42.75	.....	.....	.....	39.0	12.4	4.0
No. 562	44.5	43.00	43.25	42.50	.....	.....	.....	39.0	12.4	4.5
No. 563	44.5	42.75	43.00	42.50	.....	.....	.....	39.0	12.4	4.5
No. 564	44.5	43.25	43.50	43.00	.....	.....	.....	39.5	11.3	3.2
No. 565	44.5	42.50	42.75	42.25	.....	.....	.....	39.0	12.4	5.1
Average	**44.5**	**42.90**	**43.15**	**42.60**	.....	.....	.....	**39.1**	**12.2**	**4.3**
No. 591	.....	.....	.....	.....	44.5	43.25	43.00	39.5	11.3	3.2
No. 592	.....	.....	.....	.....	44.5	43.00	43.00	39.5	11.3	3.2
No. 593	.....	.....	.....	.....	44.5	43.25	43.25	40.0	10.0	4.0
No. 594	.....	.....	.....	.....	44.5	43.00	43.00	39.5	11.3	3.2
No. 595	.....	.....	.....	.....	44.5	43.25	43.25	39.5	11.3	4.0
Average	.....	.....	.....	.....	**44.5**	**43.15**	**43.10**	**39.6**	**11.0**	**3.5**

The samples described in Table XIII were taken from bales 566 to 570, used for the investigations recorded in Table XIV. This hay was baled on June 1, and the samples taken one month later had 12.2 per cent of moisture, while the five samples taken two months after baling averaged only 11 per cent of moisture. The weather during July and August was unusually dry and hot, so that the loss of 1.2 per cent of moisture from July 1 to August 4 is not excessive, even for baled hay. The 44.5-ounce samples which were inclosed in cotton bags and suspended under a shelter where the air could circulate freely about them lost in the same period an average of 4.3 per cent of moisture. This loss probably left the samples practically air dry, since the samples taken from the bales August 4 lost only 3.5 per cent during the period from August 4 to August 24.

SHRINKAGE OF HAY AFTER STORING AND VARIATION IN WEIGHT DUE TO CHANGES IN ATMOSPHERIC HUMIDITY.

In order to determine just what shrinkage in weight might be expected in baled hay and also the effect which radical changes in atmospheric humidity might have on this weight, four bales of oat hay were weighed at intervals during the season from June 1 to December 1, 1913, and five bales during the season from June 1, 1914, to February 25, 1915, at Chico, Cal. The record of these weights is given in Table XIV.

TABLE XIV.—*Shrinkage of oat hay after baling and variation in weight, due to changes in atmospheric humidity, at Chico, Cal., in 1913 and 1914–15.*

Bale.	Weight.								
	When baled, June 1.	July 7.	Aug. 1.	Sept. 25.	Nov. 4.	Dec. 1.	Loss,[1] June 1 to—		Gain,[1] Sept. 25 to Dec. 1.
							Sept. 25.	Dec. 1.	
Tests in 1913:	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent*	*Per cent.*
No. 1	225.0	221.0	217.5	213.0	215.0	216.5	5.3	3.8	1.5
No. 2	240.0	231.5	230.0	227.0	230.0	231.0	5.4	3.8	1.6
No. 3	245.0	237.0	234.0	230.5	233.0	235.0	5.9	4.1	1.8
No. 4	265.0	256.0	254.5	252.0	253.0	254.0	4.9	4.2	.7
Average	**243.8**	**236.4**	**234.0**	**230.6**	**232.8**	**234.1**	**5.4**	**4.0**	**1.4**

	When baled, June 1.	July 1.	Aug. 31.	Oct. 16.	Dec. 17.	Feb. 2, 1915.	Loss,[1] June 1 to—		Gain,[1] Aug. 31 to Feb. 25.
							Aug. 31.	Feb. 25, 1915.	
Tests in 1914–15:	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*	*Per cent.*
No. 566	160	150.25	147.75	147.75	152.00	158.5	7.7	0.9	6.8
No. 567	190	176.50	172.50	172.50	175.25	182.5	9.2	3.9	5.3
No. 568	165	154.00	151.75	152.25	155.50	162.0	8.0	1.8	6.2
No. 569	200	189.00	184.50	184.50	187.75	194.0	7.8	3.0	4.8
No. 570	175	163.00	161.00	161.50	164.25	172.5	8.0	1.4	6.6
Average	**178**	**166.55**	**163.50**	**163.70**	**166.95**	**173.9**	**8.1**	**2.2**	**5.9**

[1] In figuring all the percentages, the original weight of the bale was taken as the base.

It is unfortunate that no determination of the moisture percentage was made for the hay used in 1913 and also that the weights were not continued through the winter, so that the gain due to increase of atmospheric humidity could have been more fully recorded. A comparison of the results in 1913 with those in 1914 indicates that the hay used in 1913 was somewhat drier than that used in 1914, since the total shrinkage was less; however, this may have been due, to some extent at least, to the character of the season. July and August in 1914 were unusually dry, while the months of December, January, and February, following, were extremely wet. The month of November, 1913, was also quite wet, having a precipitation of 8.5 inches and 21 cloudy or partly cloudy days. Under the extreme conditions in 1914, the variation in moisture content of the oat hay was quite large. The shrinkage in weight from the time of baling, June 1, to August 31, when the weight was least, amounted to 8.1 per cent of the original weight. Such a loss in weight would require the producer to advance the price of his hay considerably after holding it in storage several months, in order to protect himself against loss. The Ohio Agricultural Experiment Station [1] found a shrinkage of 5.7 per cent in baled oat straw when stored on a barn floor from September until

[1] Hickman, J. F. Experiments with oats. Ohio Agr. Exp. Sta. Bul. 57, p. 111, 9 tab., 1894.

March of the following year. Jordan[1] in his work at the Pennsylvania State College, 1882, found the loss of weight on hay stored in a barn to average 24 per cent. On this basis he figured that hay sold for $10 per ton when taken from the field should bear a price of nearly $12.50 per ton at the beginning of winter, provided no conditions affecting the price had changed other than loss in weight. Calculation indicates the exact price warranted by such a change in weight to be about $13.15 rather than $12.50 per ton. A loss of 8 per cent in weight when the price of hay was about $10 per ton at baling time would require an advance of 85 cents to $1 per ton, in order to insure the owner against loss.

Table XIV also shows that at Chico, Cal., baled hay following its loss of weight during the dry summer months takes up moisture during the wet winter months and gains back nearly all the weight lost, so that there is only a slight difference in weight between the time of baling and the weight at the end of the following February. The difference in this case was only 2.2 per cent, the hay having taken up 5.9 per cent of moisture between August 31 and February 25. This gain did not really begin, however, until after the October 16 weighing.

An almost equivalent gain was found in 1913, where the baled hay showed a gain in weight between September 25 and December 1 equal to 1.4 per cent of the original weight of the bale. At Chico, Cal., holding the hay until late winter would, it seems, overcome to a great extent any decrease in weight caused by loss of moisture during the summer months. This gain, however, takes place slowly. It appears from a consideration of the results obtained in both years that baled hay in a humid atmosphere will take up about 1.5 per cent of moisture the first month and in four months increase in weight approximately 6 per cent.

The shrinkage in loose timothy hay and the variation in its weight because of changes in atmospheric humidity are shown in Table XV.

The hay used in both lots 1 and 2 was practically pure timothy which was cut July 10. The hay in lot 1 was allowed to cure in the field and the 108.5 pounds were taken from the windrow July 11, when it appeared to be in about the right condition for placing in the mow. The hay in lot 2 was taken immediately after cutting and weighed, while green, 512 pounds. After weighing, it was spread out on a canvas and allowed to cure until the following day, being turned or stirred several times to hasten the drying process. On July 11 it was placed in burlap sacks and removed to a barn, where it was kept under the same conditions as lot 1. The first weighing of lot 2 was made on July 17, and even at this date it was evidently not so dry as lot 1 had been on July 11, although both lots appeared

[1] Jordan, W. H. Experiments and investigations conducted at the Pennsylvania State College, 1881–2, p. 7–14. Harrisburg, Pa.

dry enough on that date to place in a mow. The weight of the hay at this stage, when it was supposedly ready to be placed in a barn, is used as the base for figuring all percentages.

TABLE XV.—*Shrinkage of timothy hay after storing and variation in weight due to changes in atmospheric humidity, New London, Ohio, 1914.*

Date of weighing.	Lot 1.			Lot 2.			Weather conditions.
	Weight.	Percentage of original weight.	Loss in weight.	Weight.	Percentage of original weight.	Loss in weight.	
	Pounds.		*Per cent.*	*Pounds.*		*Per cent.*	
July 10							Clear.
July 11	108.5	100.0	0				Do.
July 17	103.5	95.4	4.6	295.25	100.0	0	Do.
Aug. 27	97.5	89.9	10.1	246.00	83.4	16.6	Rain, Aug. 6.
Sept. 2	101.0	93.1	6.9	250.00	84.7	15.3	Rain.
Sept. 11	99.5	91.7	8.3	250.75	85.0	15.0	
Sept. 21	97.5	89.9	10.1	242.25	82.1	17.9	Very dry.
Sept. 28	97.5	89.9	10.1	244.75	83.0	17.0	Clear.
Oct. 5	96.5	88.9	11.1	243.75	82.6	17.4	Cloudy.
Oct. 13	99.0	91.2	8.8	251.75	85.3	14.7	Rain on several preceding days.
Oct. 19	100.5	92.6	7.4	255.50	86.6	13.4	Cloudy and some rain on every day since Oct. 13.
Oct. 26				253.00	85.8	14.2	Clear from Oct. 20 to 23; Oct. 24, rain; Oct. 25, clear; Oct. 26, rain.
Nov. 2				250.75	85.0	15.0	Weather clear nearly all the time since Oct. 26.
Nov. 11				247.75	84.0	16.0	Weather clear since Nov. 2.
Dec. 2				252.00	85.4	14.6	Cloudy for four or five days preceding Dec. 2. Rain on two days.

The seasonal effect is not so marked in this instance as it was in the alfalfa at Chico, Cal., but the more frequent weighings provide an opportunity to observe the almost immediate response of loose hay to changes in atmospheric humidity. This point is illustrated best by the increase in weight during the period from October 13 to October 26, a maximum increase of 4 per cent over the weight registered on October 5 being noted on October 19. This decided increase in weight is accounted for by a period of almost continuous rain between these dates. Clear, sunny weather after October 26 caused sufficient loss of moisture to reduce the weight 2.6 per cent by November 11, showing that even as late as this in the season dry, sunny weather would affect the moisture content noticeably.

The average amount of shrinkage from a field-cured condition in lot 1 was 8.6 per cent, while in lot 2 the shrinkage was 15.6 per cent. A compilation [1] of the results obtained at several experiment stations showed an average shrinkage of 17.9 per cent in timothy when it was stored in a barn from 5 to 10 months. These figures represent fairly well the shrinkage that is to be expected in timothy hay which has been stored in a haymow, but more data on this point are needed.

[1] Vinall, H. N., and McKee, Roland. A digest of literature relating to the moisture content and shrinkage of forage. *In* Jour. Amer. Soc. Agron., v. 8, no. 2, 1916.

SUMMARY.

The variation in moisture content in field-cured forage often gives rise to errors greater in amount than the differences in yield between improved varieties or different methods of culture.

A study of the use of samples in correcting forage yields indicates the following results:

(1) Air-dried samples are a little less accurate than oven-dried samples, but the difference is so small that the air drying of samples can be relied upon for all practical purposes in correcting forage yields.

(2) Much greater extremes are found in the samples of field-cured material than in the samples of green material, indicating that replication of samples is more important in the former than in the latter.

(3) Corrections by means of samples can be accurately made from either green or field-cured material, provided care is used in sampling.

(4) Considering accuracy of results, facility of handling, and ease in figuring percentages, 5-pound samples of field-cured material and 10-pound samples of green material are recommended as the most desirable sizes for practical use.

(5) Samples need not be replicated more than three times.

(6) The percentage of moisture in the different crops at that period of growth when they are ordinarily harvested for forage was as follows: Alfalfa at Chico, Cal., 75 to 78 per cent; average, 76.9 per cent. Alfalfa at Arlington Farm, Va., 74 to 76.5 per cent; average, 75.2 per cent. Tall oat-grass and orchard-grass mixture at Arlington Farm, Va., 71 to 73 per cent; average, 72 per cent. Timothy at New London, Ohio, when in full bloom, average, 67.2 per cent. Sorghum at Amarillo, Tex., 70 to 73 per cent; average, 71.2 per cent. These percentages are probably near the average for each crop, but the fact that McKee found 85.8 per cent and Farrell an estimated 79.5 per cent of moisture in alfalfa indicates that it will be impossible to establish any arbitrary percentage of moisture in the green plant as a basis for correcting forage yields.

(7) The average amount of moisture in field-cured material was as follows: Alfalfa, 22.3 per cent; timothy, 20.3 per cent; tall oat-grass and orchard-grass mixture, 29 per cent; sorghum, 43.2 per cent. The moisture content of field-cured material varies so widely that it can not be foretold with accuracy.

The use of the sample method in correcting forage yields would greatly assist in standardizing agronomic data and do much to promote greater accuracy in field tests.

The system of correcting yield data by the use of air-dried samples is of most value in succulent crops like sorghum and Sudan grass and is of least value in fine-stemmed plants like millet, which cure quickly and rather completely.

The relation of the moisture content to the stage of development in the plants was studied in alfalfa, timothy, and sorghum. The results were as follows:

(1) Alfalfa at Chico, Cal.: Very young (12 inches high), 78.9 per cent; one-tenth in bloom, 77.1 per cent; full bloom, 74.6 per cent; past full bloom, 73.4 per cent.

(2) Sorghum at Amarillo, Tex.: Very young, 90.6 per cent; shooting for heads, 87.1 per cent; beginning to head, 84.8 per cent; full bloom, 80.4 per cent; seed ripe, 75.3 per cent.

(3) Sorghum at Hays, Kans., varied from 89.2 per cent when very young to 73.2 per cent when seed was ripe, showing practically the same gradations as at Amarillo, Tex.

(4) Timothy at New London, Ohio: Very young (10 to 12 inches high), 77.5 per cent; just heading, 76.6 per cent; early bloom, 71.4 per cent; full bloom, 67.2 per cent; leaves drying, 58.6 per cent; seed mature, 51.2 per cent.

(5) The excessive percentage of moisture in young sorghum explains the very chaffy character of sorghum hay when the crop is cut too soon, and the 90 per cent loss in weight is an additional reason why sorghum should be fairly mature before it is harvested.

(6) The moisture content of any crop at a given stage of maturity is not constant, but may vary with the conditions under which the crop is grown.

A study of the rate of loss of moisture in forage during the early stages of curing shows the following results:

(1) The approximate losses in the different crops were—

Crop and location.	Moisture loss.				
	½ hour.	1 hour.	2 hours.	3 hours.	4 hours.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Alfalfa at Chico	.....	17	35	.....	69
Alfalfa at Arlington Farm	6	14	23	28	32
Tall oat-grass and orchard grass at Arlington Farm	5	12	24	30	34
Timothy at New London	6	10	18	25	30
Sorghum at Hays	2	5	9	12	13

(2) The rate of loss of moisture after cutting differs in different varieties of the same crop, as well as in different crops.

(3) Although the Arabian alfalfa loses moisture faster than the Peruvian or ordinary alfalfa in the first one or two hours after cutting, still the total percentage of moisture is about the same for the three varieties.

(4) A high percentage of leaf surface in alfalfa varieties is correlated with a rapid loss of moisture immediately after cutting, but it does not indicate a high moisture content.

Studies of the variation in the moisture content of growing alfalfa during a single day at Chico, Cal., show an average of 1 per cent more moisture in the alfalfa at 8 o'clock a. m. than at 3 o'clock p. m.

Studies of the shrinkage in hay after storing and variation in moisture content due to changes in atmospheric humidity made with baled oat hay at Chico, Cal., and loose timothy hay at New London, Ohio, indicate results as follows:

(1) At Chico, Cal., where the atmospheric humidity changes radically from the dry summers to the wet winters, baled oat hay showed a shrinkage in 1914 of 8.1 per cent between June 1 and August 31, and a gain in weight from August 31, 1914, to February 25, 1915, of 5.9 per cent of the original weight.

(2) The results at Chico, Cal., indicate that even baled hay responds noticeably to changes in atmospheric humidity, and that hay dealers are justified in taking into account the shrinkage of their hay when fixing prices.

(3) The results secured at New London, Ohio, with loose timothy indicate a shrinkage of 8.6 per cent in one lot and 15.6 per cent in another lot when the hay was stored in a barn for about three months. The effect of a week of rainy weather was indicated by an increase of weight in the loose hay.

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